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It's our 100th issue!

In June 2012, the very first issue of **All About Space** was launched – and I remember

it like it was yesterday. At the time I was serving as a staff writer for UK magazine *Astronomy Now*, but I was immediately intrigued by its energy, vibrant design and how it effortlessly delved into some of the most complex topics in the universe. Flicking through its 100 glossy pages, I just knew I had to get involved.

That day came in November 2013 when I joined as a full-time staff writer, and what a ride it has been: from interviewing NASA astronauts to jetting off to Tenerife, Poland and America to get the latest space scoops for our readers, **All About Space** has – month-by-month – kept you up to date on the latest in space science and space exploration. This

month, and on top of your favourite features, Q&As, observing challenges and competitions, we've had a reunion: past and present staff reveal the very best bits of working on the magazine, providing a behind-the-scenes look and their favourite moments of all time.

Before I sign off, I wanted to thank you for being such an important part of the **All About Space** community – whether you've been with us since issue 1 or have only just joined us, we wouldn't exist without your loyalty to the brand.

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Gemma Lavender
Editor-in-Chief

Our contributors include...



Jonathan O'Callaghan
Space science writer
Meet space's strangest object: Planck stars. From how they're formed to their weird explosions, Jonathan has the details.



Richard Edwards
Science writer
Richard reports on the pressing issue of space junk and – if we don't find a way to minimise it – what our future could look like in low-Earth orbit.



Didier Queloz
Astrophysicist
Didier and Michel Mayor reveal more about their Nobel Prize win and how their discovery of the first exoplanet changed our understanding of the universe.



Baljeet Panesar
Space science writer
Ready for a tour of the universe's most stunning star-forming regions? Baljeet has the shortlist of some wondrous cradles of stellar life and death.

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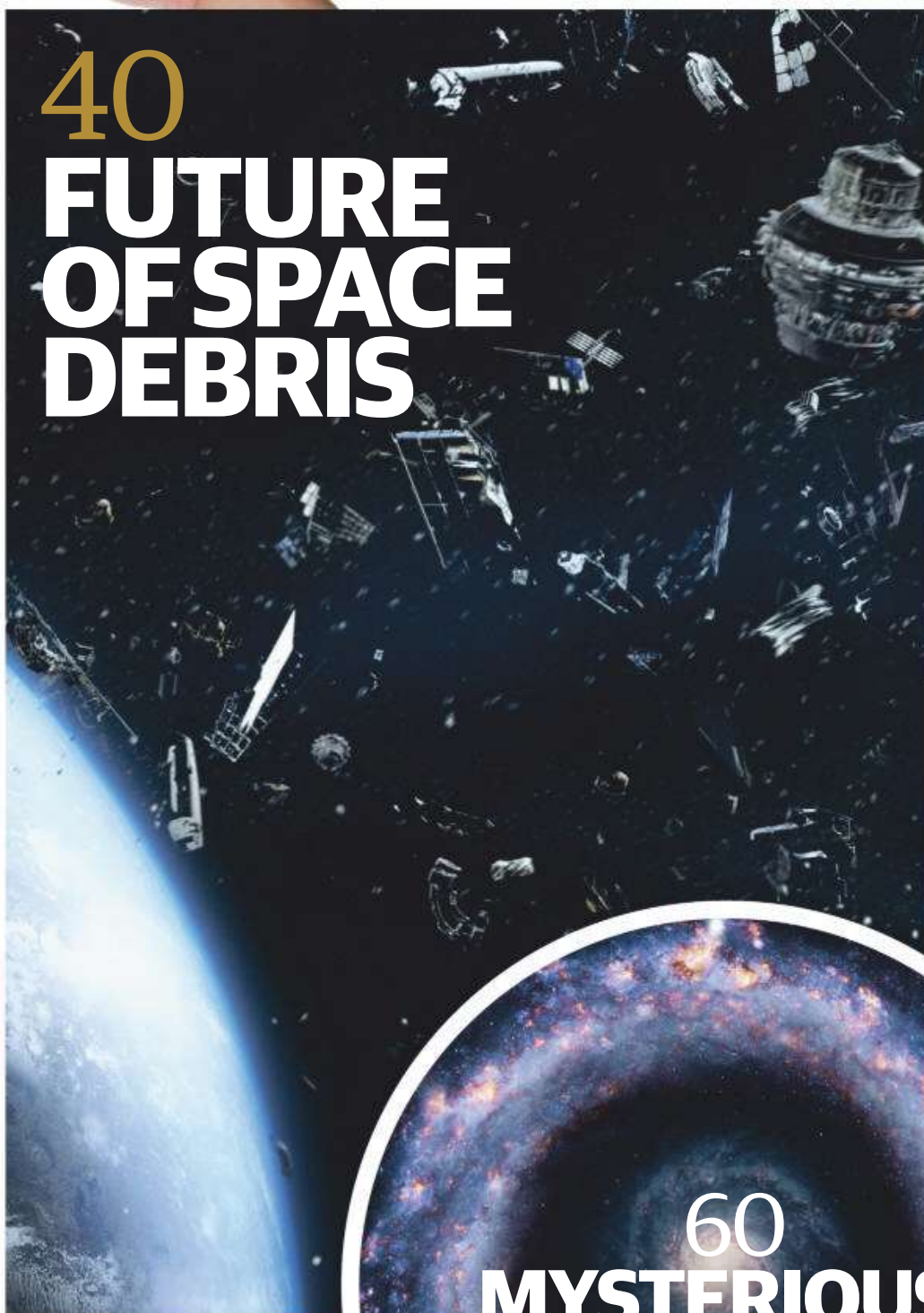


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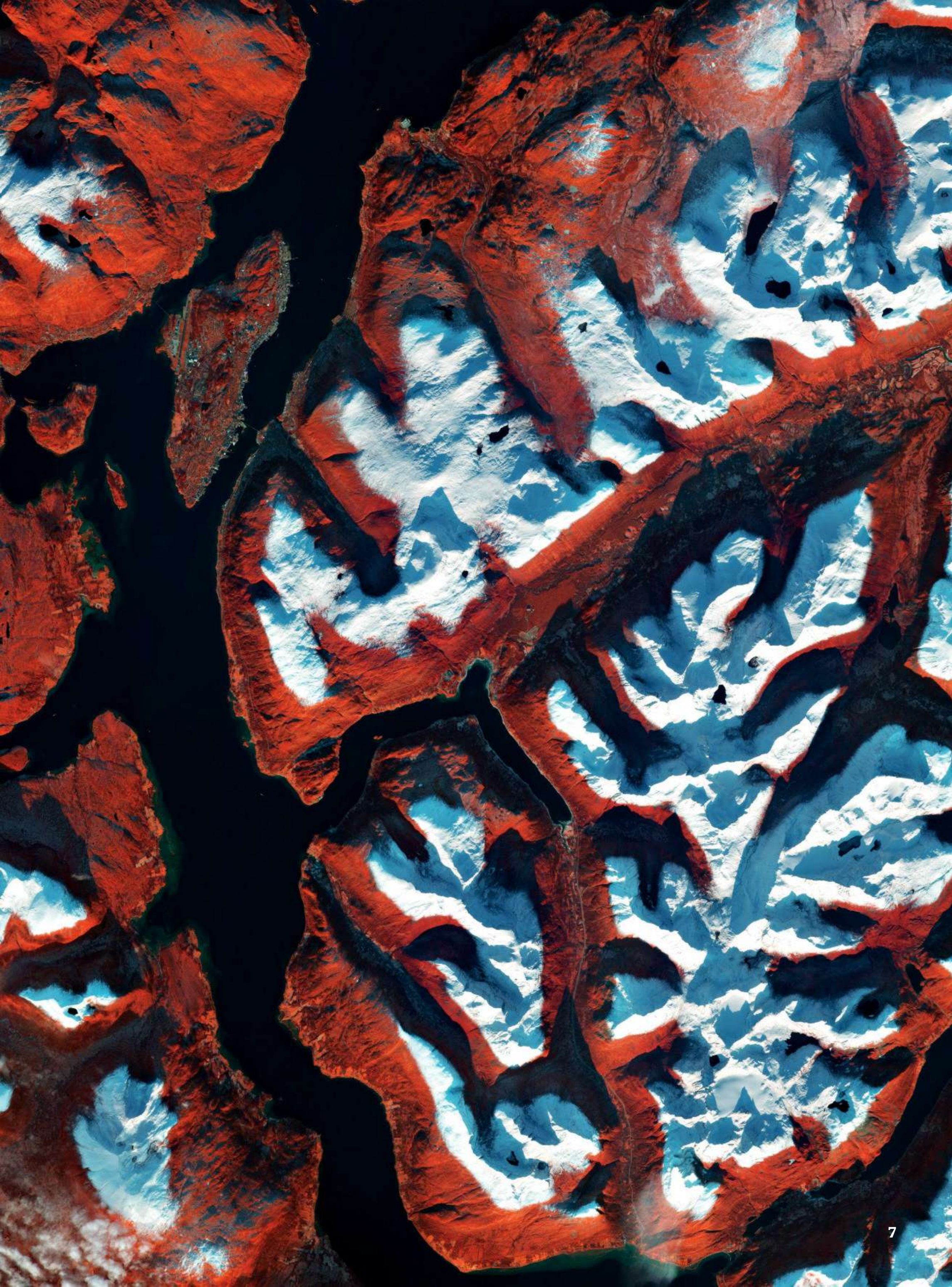
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A festive feel to Norway

The Earth can offer some equally stunning sights by telescope, and this birds-eye view of Tromsø, Norway, is imaged here by the European Space Agency's (ESA) Copernicus Sentinel-2 satellite. This colourful combination shows the mountains of the Scandinavian country with a festive twist, flaunting the white snow that sits on the tips of the mountains and the 'infrared' land, which is an indication of its vegetation. Tromsø is a remarkable place to visit as it sits near the Arctic Circle, and when the Sun sets in late November, it doesn't rise again until January.



The story behind our stars

There is more to this image of the Milky Way than meets the eye. Captured by the European Southern Observatory's (ESO) Very Large Telescope (VLT), the unprecedented detail in this shot of our galaxy's central region has uncovered important details about the star formation within.

Astronomers at the helm of the Chilean instrument, which comprises of four 1.8 metre-aperture Auxiliary Telescopes, discovered that 80 per cent of the stellar members in our Milky Way's heart formed during its early history, between 8 and 13.5 billion years ago. During the following 6 billion years, all was quiet until a burst of rapid star formation erupted some 1 billion years ago.

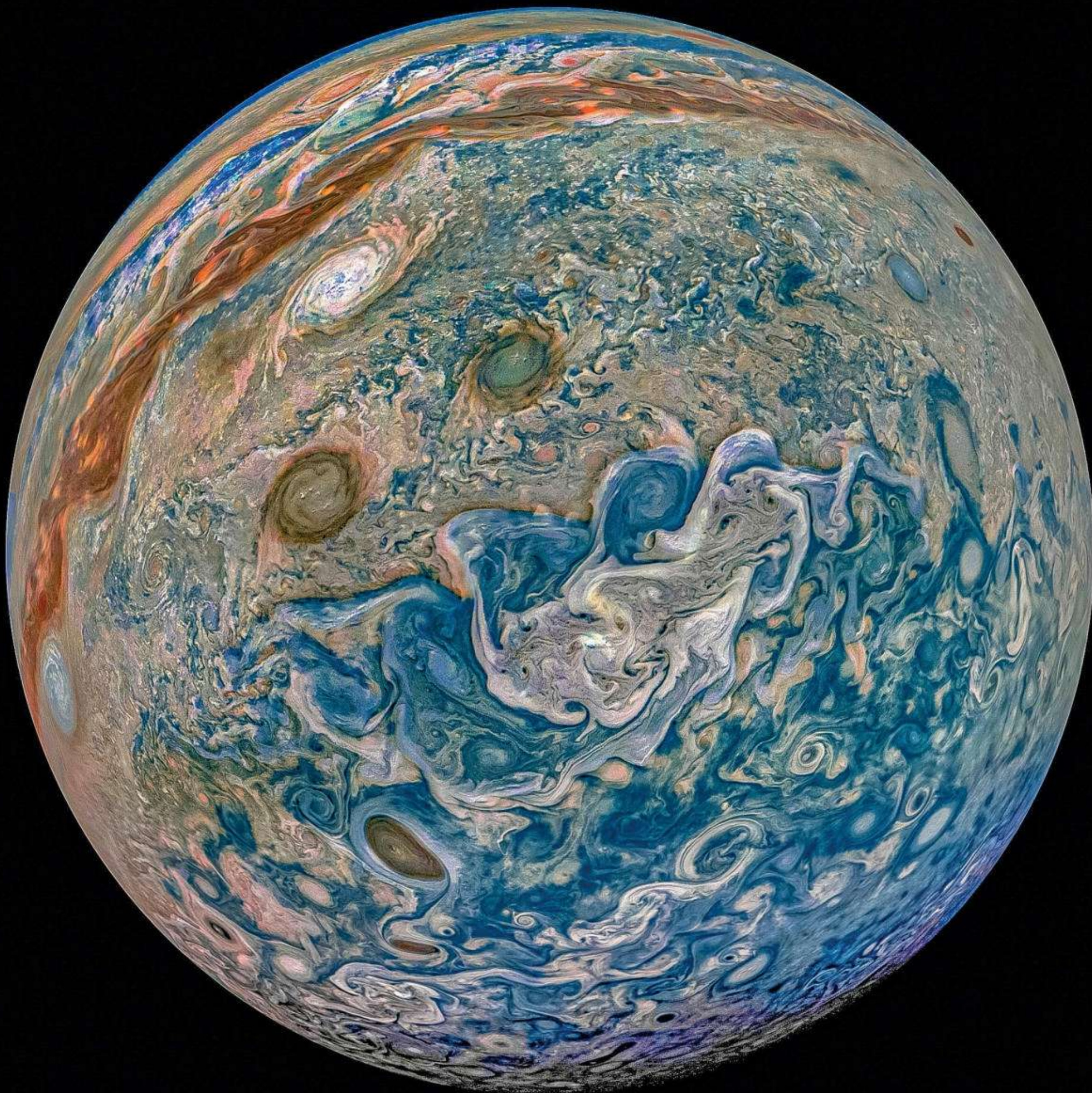
© ESO

Starliner tests reach their conclusion

On 22 December 2019, Boeing conducted a historic test launch for its CST-100 Starliner space capsule. The 'Orbital Flight Test' was pivotal in testing an uncrewed landing in accordance with NASA's Commercial Crew Program.

Here the Starliner capsule is stationary after it successfully deployed its air bags and parachutes shortly after launching over White Sands, New Mexico. Although the capsule didn't reach its intended target – the Space Station – the test was key in understanding more about its systems.





Jovian beauty

This image has been given the nickname the 'exotic marble', and it is easy to see why, as this gaseous sphere of storms and vibrant colours on the face of Jupiter will capture the imagination of many. NASA's Juno mission is still swinging past the planet from pole to pole, collecting important data and beautiful images during these close-up inspections.

Instrument JunoCam is tasked with capturing images of the Jovian king on its orbital loops. It is then up to citizen scientists to create masterpieces like these from them. The individual in this case was Prateek Sarpal, who emphasised the breathtaking, stormy cloud layers in this shot taken on 12 September 2019.

© NASA/JPL-Caltech

Red sprite at night, astronomers' delight

Overlooking Acadia Lake, Oklahoma, these mysterious red patches of lightning in the upper atmosphere are known as sprites. These bright patches are actually enormous electrical discharges that occur above thunderstorms. Not much is known about them as they are incredibly difficult to study through the storms, and even if you can spot them, they propagate much too quickly into space. Not only are images such as this one, captured by outdoor photographer Paul Smith, intoxicating, but they are a fascinating rarity.

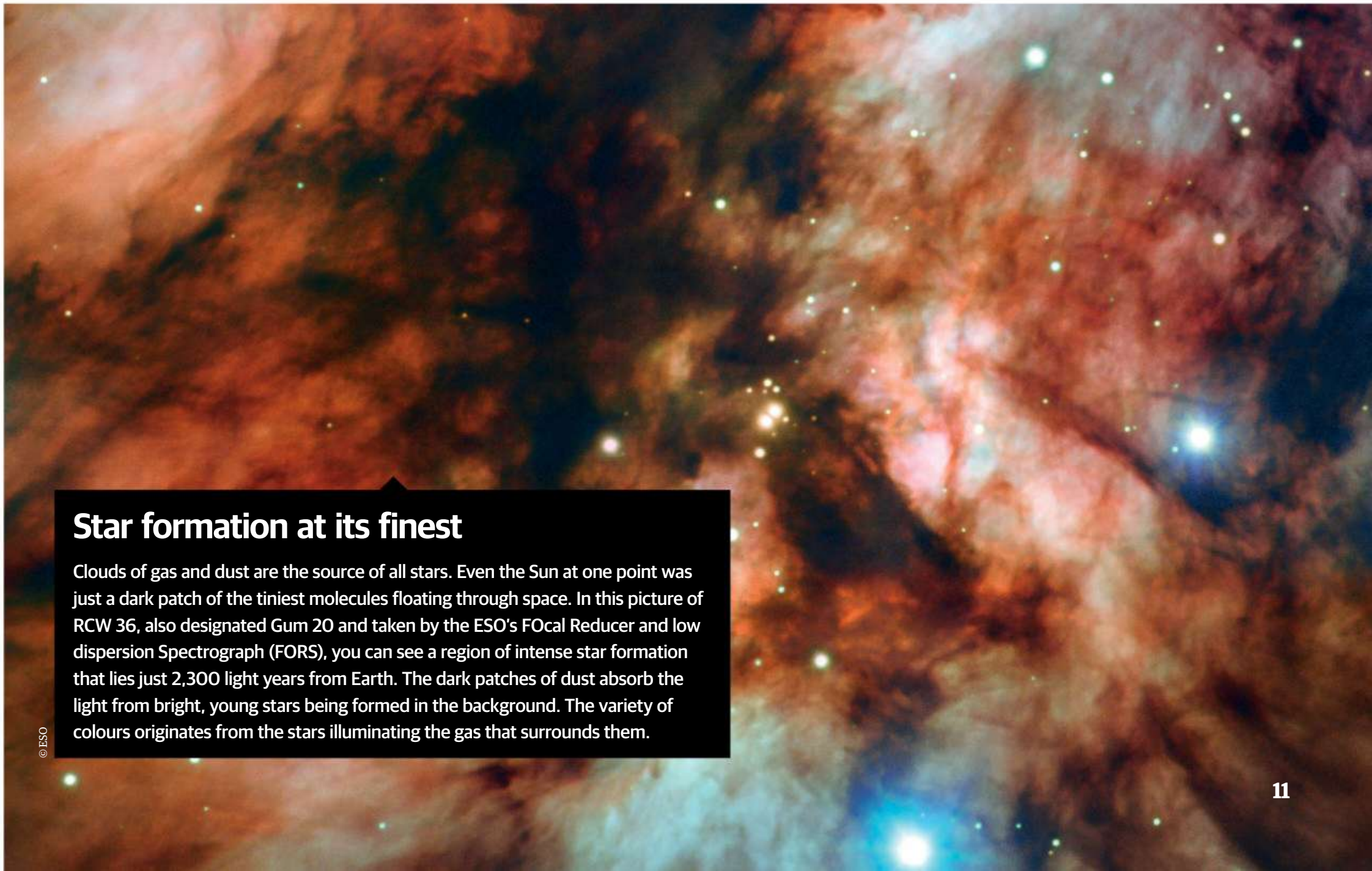


Mars 2020 rover's first driving test

Now that 2020 has arrived, another decade full of groundbreaking space exploration missions is set to begin. The start of the era will see NASA launch its Mars 2020 rover to the Red Planet – blast off is scheduled for July.

Currently, the rover is being examined and tested to the maximum to ensure it's ready for life on the Red Planet. On 17 December 2019, Mars 2020 went on a driving test in preparation for navigation around Jezero crater as it hunts for microbial life.





Star formation at its finest

Clouds of gas and dust are the source of all stars. Even the Sun at one point was just a dark patch of the tiniest molecules floating through space. In this picture of RCW 36, also designated Gum 20 and taken by the ESO's Focal Reducer and low dispersion Spectrograph (FORS), you can see a region of intense star formation that lies just 2,300 light years from Earth. The dark patches of dust absorb the light from bright, young stars being formed in the background. The variety of colours originates from the stars illuminating the gas that surrounds them.



NASA's planet hunter uncovers Earth-size world in habitable zone

Words by Mike Wall

The Transiting Exoplanet Survey Satellite (TESS) has discovered a roughly Earth-size planet in the habitable zone of its host star, the zone of orbital distances where liquid water could be stable on a world's surface. The newfound exoplanet, known as TOI 700 d, lies just 101.5 light years from Earth, making it a good candidate for follow-up observations by other instruments, scientists added.

TESS found three different planets circling the star TOI 700 - TOI meaning 'Tess Object of Interest' - a red dwarf about 40 per cent as massive, 40 per cent as wide and 50 per cent as hot as Earth's Sun. The innermost world, TOI 700 b, is roughly Earth-sized and completes one orbit every ten Earth days. The centre planet, TOI 700 c, is 2.6-times bigger than our planet, meaning it's likely a gassy 'sub-Neptune', and zips around TOI 700 every 16 days.

TOI 700 d, the outermost known planet in the system, is the really intriguing one. It's just 20 per cent larger than Earth and completes one orbit every 37 days. The alien world receives 86 per cent of the stellar energy Earth gets from the Sun, putting TOI 700 d in the habitable zone.

All three planets may be tidally locked to TOI 700, always showing it the same face, just as Earth's Moon only ever shows us its near side. But tidal

locking doesn't necessarily preclude the possibility of life, astronomers say. And there's more good news regarding TOI 700: "In 11 months of data, we saw no flares from the star, which improves the chances TOI 700 d is habitable and makes it easier to model its atmospheric and surface conditions," said discovery team leader Emily Gilbert, a graduate student at the University of Chicago.

Scientists hope to pin down TOI 700 d's mass by measuring how much its gravity tugs the host star. Without knowing the mass, it's unclear how dense TOI 700 d is - and thus if it's a rocky world like Earth. In-depth observations of light that has streamed through TOI 700 d's atmosphere on its way to Earth could tell us a great deal about conditions on the alien world's surface, which remain a total mystery at the moment.

"Someday, when we have real spectra from TOI 700 d, we can backtrack, match them to the closest simulated spectrum and then match that to a model," said Gabrielle Engelmann-Suissa, a Universities Space Research Association visiting research assistant at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "It's exciting because no matter what we find out about the planet, it's going to look completely different from what we have here on Earth."

Left: Work will be done to deduce the mass and composition of the Earth-sized planet

Right: It is hoped the JWST will be a fitting successor to Hubble

Cosmic rays are tearing our satellite galaxy apart

Words by Paul Sutter

Researchers released simulations of the Large Magellanic Cloud (LMC) - a satellite galaxy of the Milky Way - and found that cosmic rays from a starburst event are starting to rip it apart.

One of the many by-products of starburst violence is the production of cosmic rays, tiny charged particles accelerated to nearly the speed of light. Cosmic rays constantly zip through the cosmos, leaping over billions of light years to wreak havoc wherever they land.

Now much hotter, gas doesn't seem so interested in staying in the LMC - or, in other words, the gravity of the LMC isn't strong enough to hold onto its own gas after these rounds of concentrated star formation and supernovae, and so the hot gas tries to leave.

Researchers looked at the simulated behaviour of something called the Magellanic Stream, a trail of hot, thin gas that wraps almost all around the Milky Way, a flow of material ejected from the satellite galaxy hundreds of millions of years ago.

Right: Violent star formation is heating the Large Magellanic Cloud (LMC)



They found a surprise: even though the cosmic rays heated up the gas in the LMC: the gas stayed inside.

The reason for this apparent contradiction is the LMC's orientation as it falls towards the Milky Way. For the past billion years or so, it's been heading for us directly, no holds barred and face-on. Because of this orientation, as the LMC swims through the loose halo of gas surrounding the Milky Way, pressure from the gas can keep a lid on things.

James Webb Telescope on track for March 2021 launch

Words by Meghan Bartels

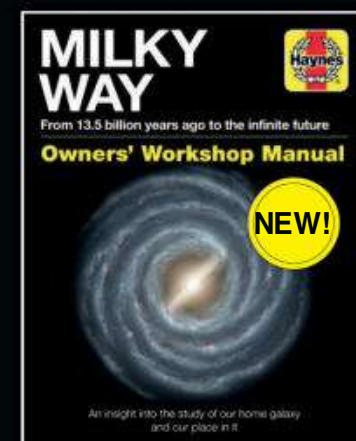
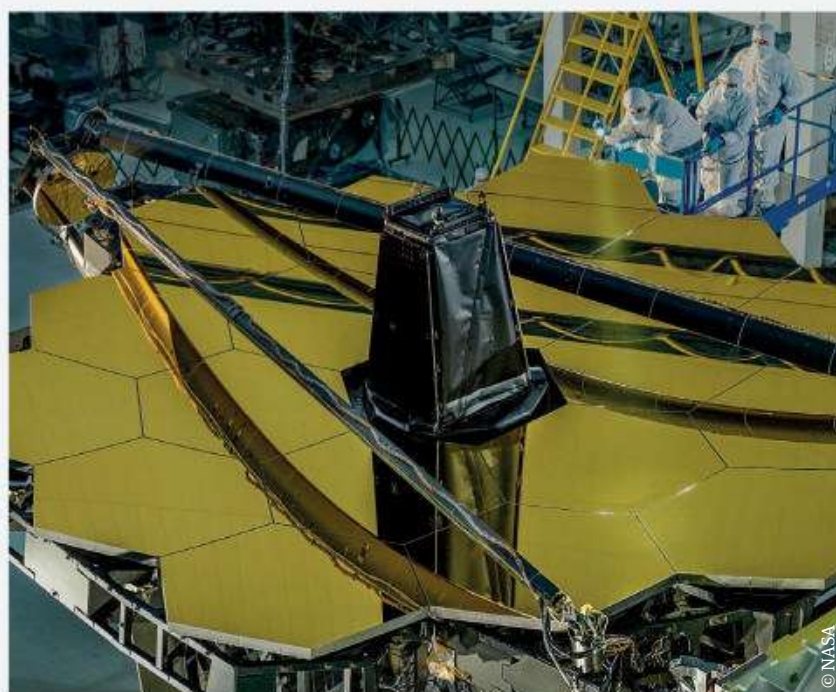
NASA's next flagship space telescope is still on track for a launch in March 2021 despite long-standing scheduling concerns, according to agency personnel. The James Webb Space Telescope has been notoriously prone to delays and cost overruns, but during two town hall meetings here at the 235th American Astronomical Society meeting, NASA leaders emphasised that the launch date set in June 2018 still holds. A second major telescope is also continuing to meet its timeline, targeting a launch in the mid-2020s. "This past year was an exciting year for James Webb," said Paul Hertz, director of the astrophysics division of NASA's Science Mission Directorate. "This is your next great observatory."

But before it can become NASA's next great observatory, Webb needs to complete a host of milestones this year. Right now the spacecraft is being packed up from the first test of its deployment. Next engineers will subject the spacecraft to the type of vibration and acoustic environments it will experience during launch on an Ariane 5 rocket.

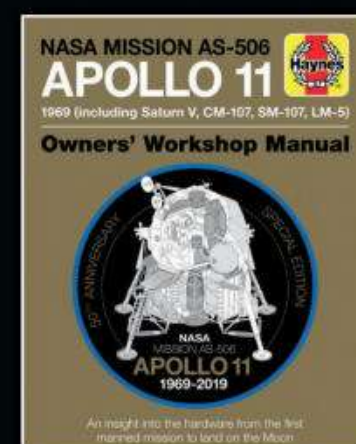
Then the mission team will test deploying it again to ensure that those environmental tests didn't create any new problems. A host of other, smaller tasks are also scheduled for this year,

according to NASA's Eric Smith. Webb is currently estimated to have cost about \$9.7 billion (£7.42 billion). One vital step will be replacing some electronics that failed during an earlier test, which Smith said is the type of work that has never been done on the telescope before.

Smith emphasised both that the bulk of the work on Webb is complete and that the activities scheduled for the next 15 months are crucial to the mission's success.



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Hubble turns 30 this year: how astronomers will celebrate

Astronomers kicked off 2020 by welcoming the 30th anniversary of NASA's venerable Hubble Space Telescope at their largest annual gathering. During the first full day of the 235th American Astronomical Society conference, a team of scientists affiliated with the instrument shared their highlights from the mission. Hubble has produced not just scientific results, but also a host of iconic images of the universe around us.

"We flooded the world with jaw-dropping pictures," Ray Villard, a long-time public affairs officer working on Hubble for the Space Telescope Science Institute that runs it, said during the event. "These pictures, they really have redefined the universe for the public, and they speak to the public at a visceral and emotional level that is far beyond the scientific understanding."

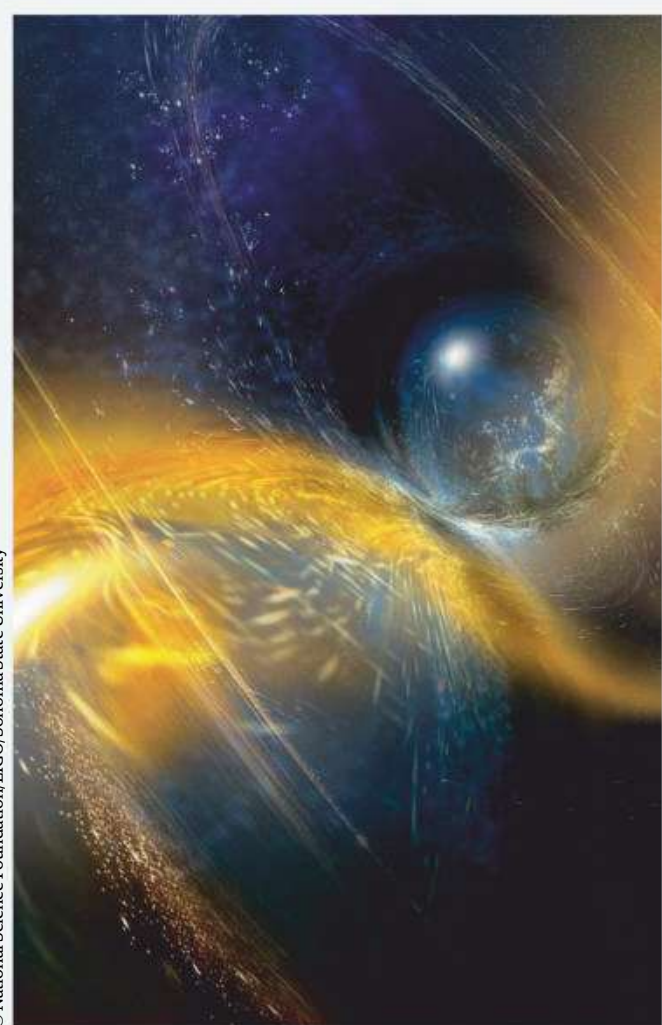
And as scientists emphasised throughout the presentation, many of Hubble's impacts couldn't

have been predicted when the instrument launched. Take, for example, exoplanets, of which zero had been identified at Hubble's launch in 1990. Now scientists know of more than 4,000 such distant worlds, and the space telescope has been a vital tool for studying and identifying them.

Hubble has been key for directly imaging exoplanets, Nikole Lewis, an astrophysicist at Cornell University, said during the event. Scientists have never actually seen most of the exoplanets they have discovered, except for those that have been directly imaged - and Hubble's data archives are allowing scientists to see more of these worlds.

"These were basically images that were taken before we knew those planets were there," Lewis said. "We were able to dig back into the archives of data and find planets that were just buried before." That research can continue even after Hubble's eventual demise.

Above: Hubble will celebrate its anniversary with more stunning space imagery



Incredible neutron star crash detected

Words by Adam Mann

For the second time ever, the Laser Interferometer Gravitational-Wave Observatory (LIGO) has spotted two ultradense stellar remnants known as neutron stars violently crashing together. The gravitational-wave event seems to have been generated by particularly massive entities that challenge astronomers' models of neutron stars. Telescopes have never seen a neutron star pair with a combined mass greater than 2.9 times that of the Sun. "This is clearly heavier than any other pair of neutron stars ever observed," Katerina Chatziioannou, an astronomer at the Flatiron Institute in New York City, said.

Researchers can't rule out that the merging entities were actually lightweight black holes or a black hole paired with a neutron star, she added. But black holes of such small stature have never been observed before either.

Left: Gravitational waves were detected originating from the collision

Right: Boeing's Starliner rests in the desert after successfully deploying its landing gear

NASA mulls next steps for Boeing's astronaut taxi

Words by Mike Wall

On 20 December 2019, Starliner launched on an uncrewed mission designed to demonstrate the capsule's ability to fly NASA astronauts to and from the International Space Station (ISS).

The test was supposed to last eight days and feature an autonomous docking with the station. But Starliner suffered a glitch with its onboard timing system shortly after liftoff and got stranded in an orbit too low to allow a rendezvous with the ISS. The reusable capsule ended up zooming around Earth by itself for 48 hours, then coming down for a picture-perfect landing in New Mexico's White Sands Missile Range on 22 December.

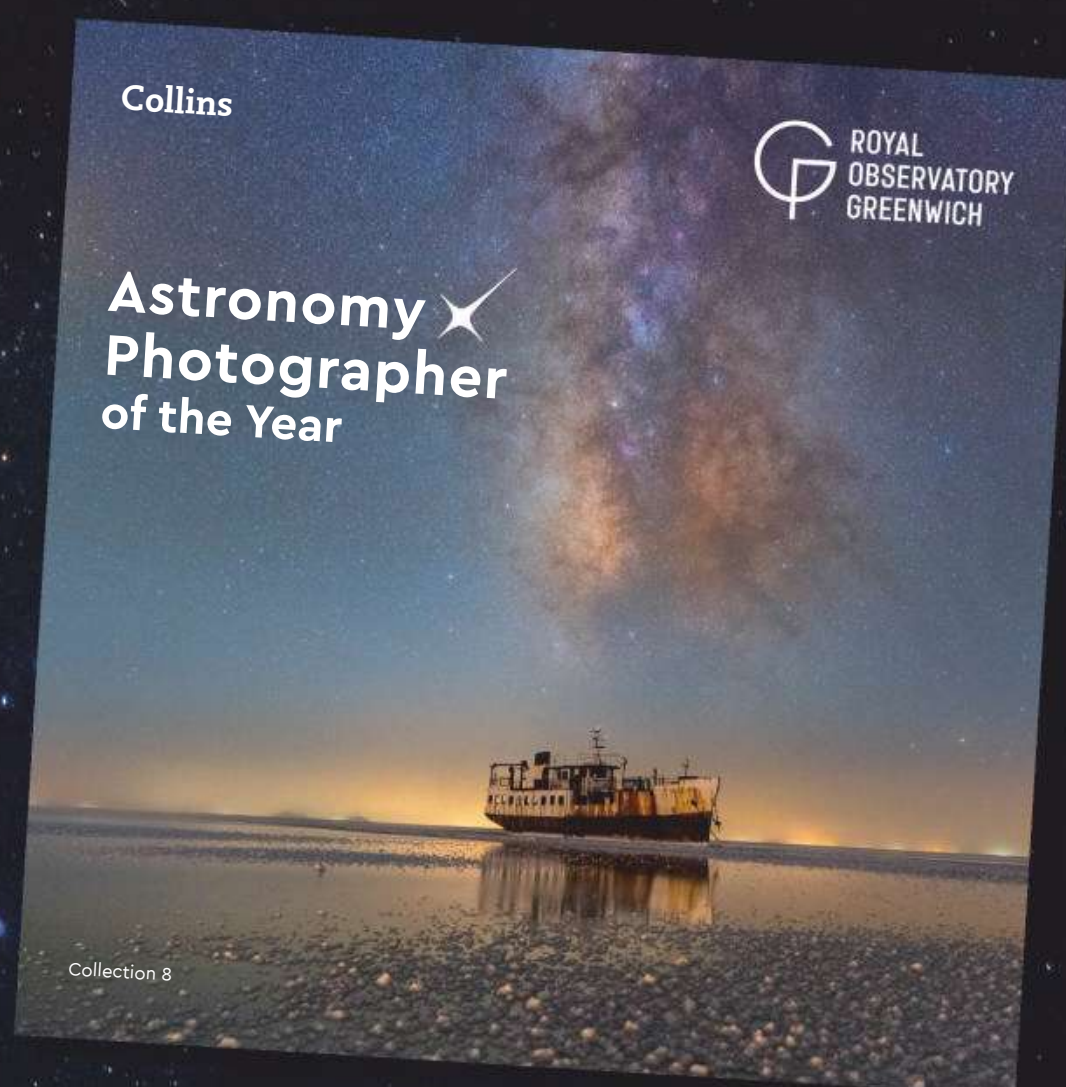
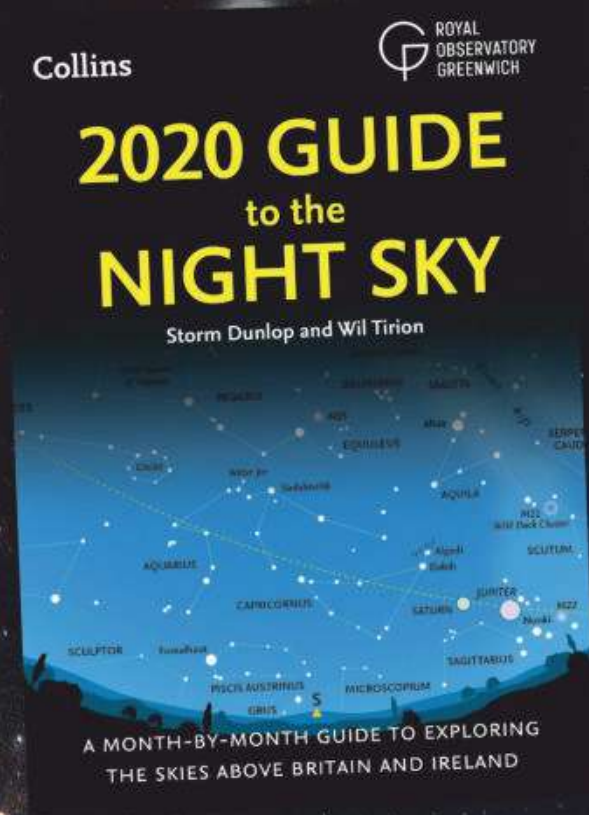
"NASA is evaluating the data received during the mission to determine if another uncrewed demonstration is required. This decision is not expected for several weeks as teams take the necessary time for this review," NASA administrator Jim Bridenstine wrote in a statement.

Bridenstine also announced that NASA and Boeing are forming a joint team to investigate Starliner's timing anomaly and figure out how to make sure it doesn't happen again.



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STRANGEST STAR IN THE UNIVERSE

Black holes might be collapsing stars that
are exploding in slow motion

Reported by Jonathan O'Callaghan

W

hat happens inside a black hole? That is a question that has long plagued astronomers, with numerous theories put forward, and numerous problems. Black holes have a gravitational pull so strong that nothing, not even light, can escape. This leads to a problem known as the 'information paradox' where information could disappear forever inside a black hole, something that doesn't hold up against our laws of physics. But an emerging theory put forward a few years ago proposes an unusual solution to this problem: that black holes are not what we think, and instead contain an object known as a 'Planck star' - collapsing stars rebounding in slow motion that, over time, emerge from view.

The idea of Planck stars was proposed in a paper by Carlo Rovelli from the University of Marseille in France and Francesca Vidotto, then of Radboud University Nijmegen in the Netherlands, in 2014. The two astronomers suggested that at the core of the black hole

What we think we know about Planck stars

They are remnants of dead stars

Planck stars are thought to be the remnant cores that are left behind after very massive stars run out of fuel and collapse at the end of their lives.

They are stuck in slow motion

As the star collapses, the intense forces of gravity cause time dilation to occur – from our point of view the collapse is slow, but it's actually very fast.

Event horizons are the outer edge of the collapse

The collapse creates what we see as a black hole, with the event horizon being the shrinking boundary of the object's immense gravitational pull. The Planck star is at the centre, surrounded by the black hole's event horizon.

They 'bounce' and explode

Once the shrinking event horizon reaches the Planck star at the centre, it bounces back in a massive explosion that could emit detectable gamma rays, appearing as gamma-ray bursts.

Solving the information paradox

Because we think Planck stars radiate out material when they explode, they would solve the paradox of where information falling into a black hole goes. That information, it seems, would be emitted back into space.



© NASA/ESA

Above: Gamma-ray bursts might be the result of Planck stars exploding in the early universe

there could exist a tiny object – a Planck star – that stores all information about infalling material into the black hole. As the black hole evaporates and its gravitational boundary – known as the event horizon – shrinks, it would eventually meet this Planck star, exploding in a violent event and allowing information to then escape into space, supposedly solving the information paradox.

Planck stars would form in much the same way a black hole does. A black hole forms when a very massive star runs out of fuel at the end of its life. With no outward pressure to counteract the incoming force of gravity on the star, it collapses into a singularity and produces a black hole. However, Rovelli and Vidotto argue, that might not be the end of the story. They suggest that a black hole is the process of a massive star exploding

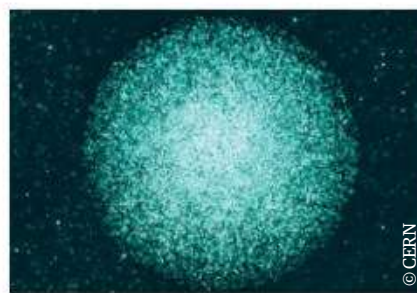
like a supernova, with its event horizon gradually shrinking over very long scales.

“The black hole forms in the sense that you have the creation of a horizon,” says Vidotto. “But on the inside, the collapse keeps on happening, and at a certain point you have new forces of quantum origin that balance the contraction. So instead of having a contraction that goes on forever and creates a singularity, you have instead these new forces that trigger a new phase that could be an expanding phase. The object that at a certain point corresponds to this maximum contraction is what we call a Planck star.”

Eventually this event horizon reaches the middle of the black hole, the singularity, where the remains of the original star have been squashed into a tiny point less than a trillionth of a trillionth of a

Bluffer's guide: loop quantum gravity

How to make two of our competing laws of physics match up with each other



Laws of physics

In physics, the Standard Model is a broad theory to explain forces and particles in the universe, while general relativity explains how gravity works.

Head to head

The Standard Model and general relativity are not compatible. One can't explain the other. Something else must be going on to make them work together.

The peace maker

Loop quantum gravity attempts to make quantum mechanics – which governs the very smallest things in the universe – compatible with gravity.

metre in size, known as the Planck length – the smallest possible length in physics. Once the event horizon reaches this point, the infalling event horizon bounces out again, and the star unleashes its matter into space. It's an event that should be fairly quick, but the intense gravity of it leads to something called time dilation, and from our point of view, everything is moving slower than it actually is. Thus, when we look at a Planck star, we are seeing the process of a massive star collapsing and rebounding essentially "in slow motion", says Vidotto. From our point of view the entire process takes billions of years, depending on the size of the black hole.

Stefano Liberati from the Scuola Internazionale Superiore di Studi Avanzati (SISSA) in Italy compares the idea to the 2014 film *Interstellar*. In the film the protagonists visit a planet orbiting near a black hole, Gargantua, where time runs more slowly owing to its immense gravitational pull. "That is basically the time dilation due to the gravitational redshift, which is a phenomenon which we know is there – it's predicted by general relativity," he says. "The idea is that the bounce [of

the Planck star] is very fast if you are running the clock on the collapsing star. But seen from outside, there is a huge gravitational time dilation."

A Planck star is a wholly unusual and unstable object, being condensed into the size of an atom. Planck star theory builds upon the idea that black holes have an event horizon and a point of near infinite mass and density at their cores, known as a singularity. The information paradox posits that it is impossible to ever know anything about this singularity, owing to the immense forces involved and the fact that nothing can escape. But if a black hole were actually a Planck star in the process of collapsing and rebounding, it could solve this paradox.

This is similar to one of the proposed theories for the end of the universe, known as the Big Crunch. Our universe is now known to be expanding at an accelerating rate, but scientists once thought the expansion might start to slow, eventually leading the universe to collapse. This would result in the opposite of a Big Bang, known as the Big Crunch or Big Bounce, where all matter in the universe would be condensed to a singularity. Once the

Above: NASA's Fermi Gamma-ray Telescope is used to study gamma rays in the universe

Below: Our best chance of finding Planck stars could be looking back to the early universe

Planck star

© NASA

What we need to know about Planck stars

How long do they take to explode?

While we think Planck stars are stellar explosions in slow motion, we aren't entirely sure how long they take. We'll need to know that if we ever want to spot one.

Where are they?

If Planck stars do really exist, it might be possible to spot some of them exploding in our night sky. However, we haven't been able to track any down as of yet.

Were they in the early universe?

It's possible Planck stars were present in the early universe, in the form of primordial black holes. If we can find some of these, we might be able to find a Planck star.

Have we seen some already?

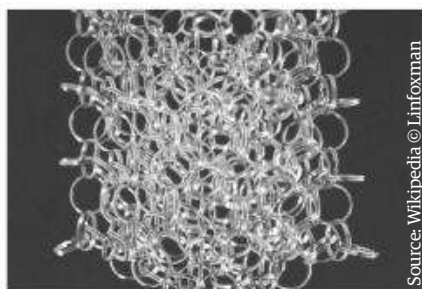
Planck stars are thought to release large amounts of gamma rays when they explode. We've already detected many gamma-ray bursts in the universe – could some of those bursts we've found be Planck stars?

What size are they?

Black holes come in a variety of sizes, but do Planck stars as well? Smaller ones would explode more quickly, so we'd be able to spot them more easily in the universe.



© ESA/Hubble & NASA



Source: Wikipedia © Linfoxman



© Getty

Loop the loop

It works by breaking down space into smaller bits. It suggests space-time is not a continuous sheet, but rather lots of smaller 'loops' joined together.

The Big Bounce

One consequence of this theory is that there was no Big Bang, but instead a Big Bounce – something that lends itself well to Planck star theory.

Einstein to the rescue

Loop quantum gravity allows us to have a quantum theory of gravity, one that relies on Einstein's equations from nearly a century ago.

How do Planck stars form?

These stars form in a similar way to black holes, but with some crucial differences

1 A star is born

A massive star is born in a cloud of dust and gas: a nebula. If the star is at least 10 to 20 times the mass of the Sun, it will have the chance of forming a black hole.

2 End of the road

As the giant star reaches the end of its life, it runs out of fuel. When this happens it can no longer support itself under its own gravity, and it collapses.

3 Going supernova

As the star collapses, its infalling material hits its core, and rebounds back into space in a violent explosion known as a supernova, leaving behind a dense core.

4 Planck star

This dense core collapses further until it reaches the smallest length possible - the Planck length, a trillionth of a trillionth of a metre in size - forming a Planck star.

5 Event horizon

The Planck star is surrounded by a region known as the event horizon, where nothing - not even light - can escape its pull.

6 Stuck in slow motion

The event horizon is actually collapsing towards the Planck star rapidly, but the strong gravity causes time dilation, making the process appear to take billions of years from the outside.

7 Big Bounce

Eventually the infalling event horizon reaches the Planck star, at which point the star rebounds outwards in a new explosion, producing a gamma-ray burst.

8 Black hole dust

The remnants of the black hole and Planck star are left behind in the form of black hole dust, the signature of which could be detected from afar.

universe reached the so-called Planck length, it would rebound again in a new Big Bang, restarting the universe.

An outstanding issue in physics is that two of our major theories, quantum mechanics and gravity, cannot be reconciled. The former explains things on a very small scale, and the latter on a very large scale, but it's difficult to make them work with each other. One solution is something called loop quantum gravity, the idea that space-time is actually made up of lots of smaller parts, or loops. This theory suggests that the universe is infinite and has always existed, rebounding in numerous Big Bounces in the same way as a Planck star.

"The idea of bouncing comes from ideas that have been developed in the framework of quantum gravity," says Carlos Barceló Serón from the Instituto de Astrofísica de Andalucía in Spain. "What you have is the universe, instead of coming from a singular point, there was a previous universe that was collapsing. And then it reaches this Planck density and then bounces back into our universe. It works very nicely. It has been the inspiration for the [Planck star theory]."

Loop quantum gravity, adds Vidotto, could also be useful in working out the lifetime of Planck stars. "There is an open question that is, 'what is the lifetime of these objects?'" she says. "How long is the life of a Planck star? In order to [answer] that we need a quantum gravity theory to make this computation, and so we are using the tools of loop quantum gravity to do this computation. It's very exciting because applying those tools to such a

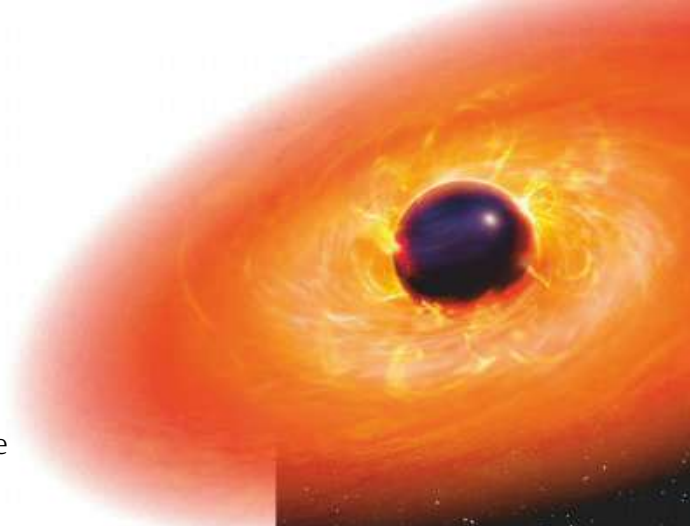
concrete scenario that may lead to the detection of something is very motivating for people working in quantum gravity."

While the Big Bounce theory is now mostly superseded by the heat death theory of the universe - that the universe will continue expanding at an accelerating rate until atoms themselves are torn apart - it does lend itself well to Planck star theory. "The idea is that inside a black hole some bounce should happen," says Vidotto. "What was novel in our approach was we started thinking about what would happen if the bounce phase doesn't go into some strange new universe, but is just a new phase that happened in the future of the black hole."

Vidotto says the idea is similar to that of a 'white hole' - essentially the opposite of a black hole, where everything escapes rather than being trapped. "You have this expanding phase like an explosion," she says. And this means such an event could be possible to see, if a black hole had progressed to this point in its life. "This is something that is observable, and this opens up new possibilities for investigating black holes," she adds, noting there may be detectable remains of this event. "We don't expect the explosion to define the end of the black hole. We expect it to have a new remnant phase that's like black hole dust."

The idea that black holes might evaporate in some way was proposed by the late Stephen Hawking, who said that black holes might be able to leak information in the form of Hawking radiation, providing a potential solution to the information paradox. Under Hawking's proposal, the black hole

Below:
Information
must live on
somewhere
in a black hole
to fit within
our current
understanding



Five facts about black holes

Here are five things we know about these unusual objects that play a crucial role in Planck stars

They come in different sizes

Black holes can range in size from microscopic to supermassive black holes, which are billions of times more massive than our Sun and found in the centre of galaxies.

They grew really fast

Black holes in the early universe somehow grew really quickly, reaching supermassive status just a billion years after the Big Bang - but scientists aren't sure how.

We've managed to take an image of one

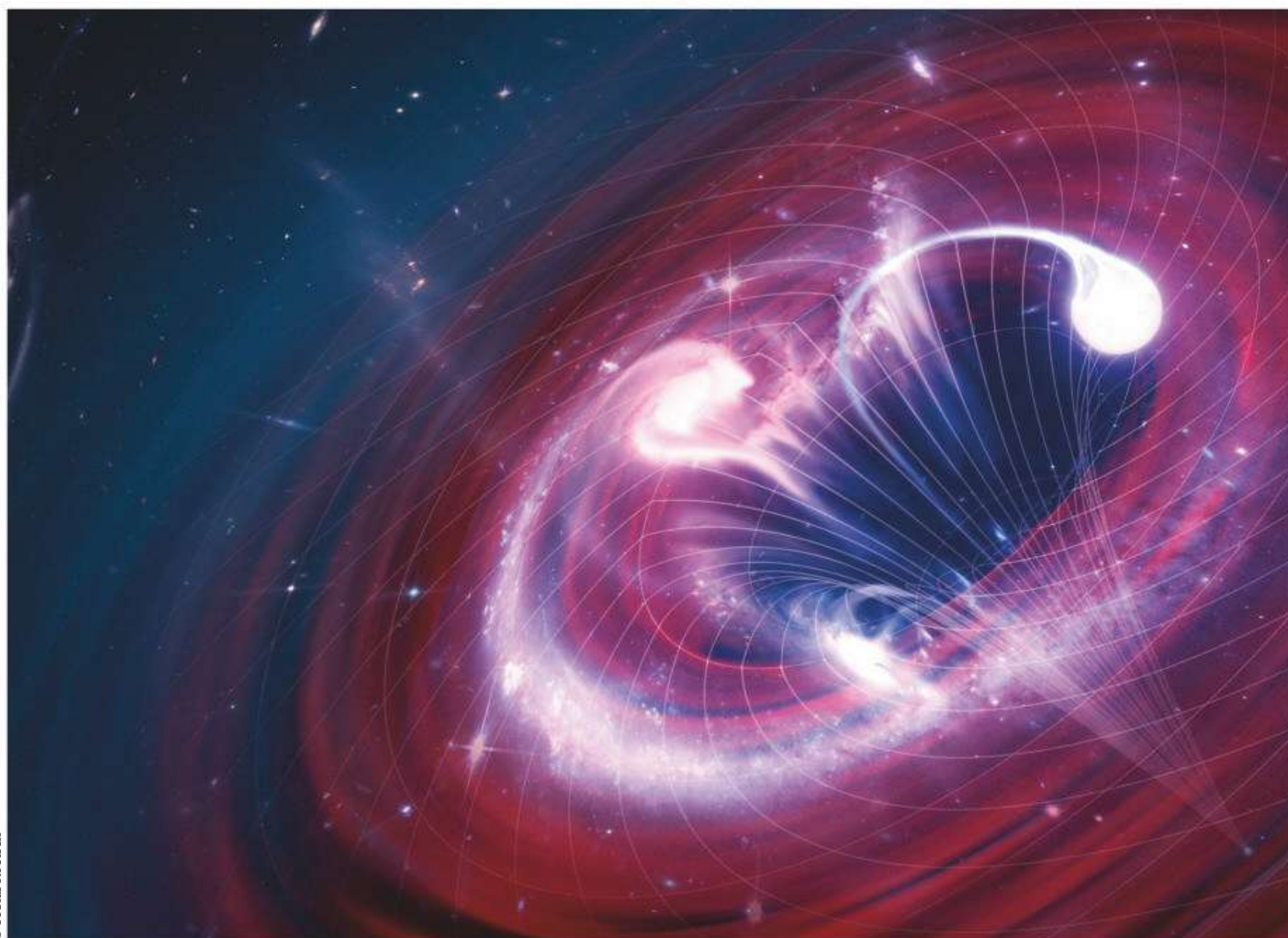
In April 2019, astronomers from the Event Horizon Telescope (EHT) project revealed they had taken the first image of a black hole, found in the nearby M87 galaxy.

Despite the name, they can be really bright

Some supermassive black holes are surrounded by swirling discs of superheated material, known as a quasar, which can be easily spotted in telescopes, although the black hole remains hidden.

There's a missing class of black holes

Astronomers believe the universe might be abundant in a medium-sized type of black hole, called an intermediate-mass black hole. However, we've struggled to find many of them so far.



Below: A black hole's gravity can be so strong that light is forced into an orbital path, creating a photon sphere



© Nicholas Forder

would gradually evaporate, leaking more and more Hawking radiation until it disappeared completely. But the Planck star theory takes this even further, suggesting it is not just Hawking radiation that escapes, but essentially everything from the Planck star when its bounce phase is over.

Serón notes that there are some issues with the theory, however, notably that this process is expected to take many billions of years, making it hard to test. "The problem with these proposals is that theoretically they are very nice," he says. "The thing is that they're very difficult to prove in real scenarios. The only chance is that some of these objects have been evaporating for a long time. They were formed with small masses at the beginning of the universe, and now they are in the last stages of evaporation. And they could lead to some of the explosions that you see in the sky."

That's something Vidotto is particularly interested in. It might be that some of these objects, if they truly exist, were present in the early universe. Thus, enough time may have passed now that they could have already exploded, letting us see the after-effects of what happened. "There seems to be a convergence in the astrophysics community about the possibility of having primordial black holes," she says. "[These] are black holes that formed in the very early universe. Those may form with a lot of different sizes. We are in particular interested in those that are smaller, so that the timescale for a

"Inside a black hole there is not a singularity, there is a Planck star... I'm pretty convinced" **Francesca Vidotto**

black hole to form and go through the Planck star phase and explode [is shorter]."

Such events would be in the form of gamma-ray bursts, among the brightest events in the universe. Some of these are thought to be produced when two objects merge together, such as neutron stars and black holes. They may also be produced when supergiant stars go supernova. However, if black holes really do contain Planck stars inside them, then it could be that some gamma-ray bursts are the result of primordial black holes from the early universe exploding.

"The original idea is that they would go for billions and billions of years, so the idea is you could see today Planck stars exploding that were formed in the early universe [like a supernova]," says Liberati. "[They] could be bouncing now. And then we would be able to see the signal now from these kinds of explosions."

The idea of Planck stars remains somewhat controversial, however. For one, it is somewhat difficult to prove they exist; peering into the early

universe to spot primordial black holes is difficult. Although some have been theorised, finding them is much harder to come by, and thus seeing any events associated with a Planck star is also difficult. And the idea of a Big Bounce for the universe also seems to go against many of our observations of the universe, which suggest it is expanding at an accelerating rate.

Vidotto, however, is hopeful that Planck stars really do exist, and continuing efforts are being made both to work on the theory of their existence, and to perform observations to look for them. She says researchers are developing new loop quantum gravity tools that could be useful in predicting some of the properties of Planck stars, and perhaps tell us what we might expect to see if we managed to spot one exploding. "This idea puts together some old ideas, but in a really new way that opens up a new direction of research," she says. "The idea that inside a black hole there is not a singularity, there is a Planck star - this is something I'm pretty convinced of."

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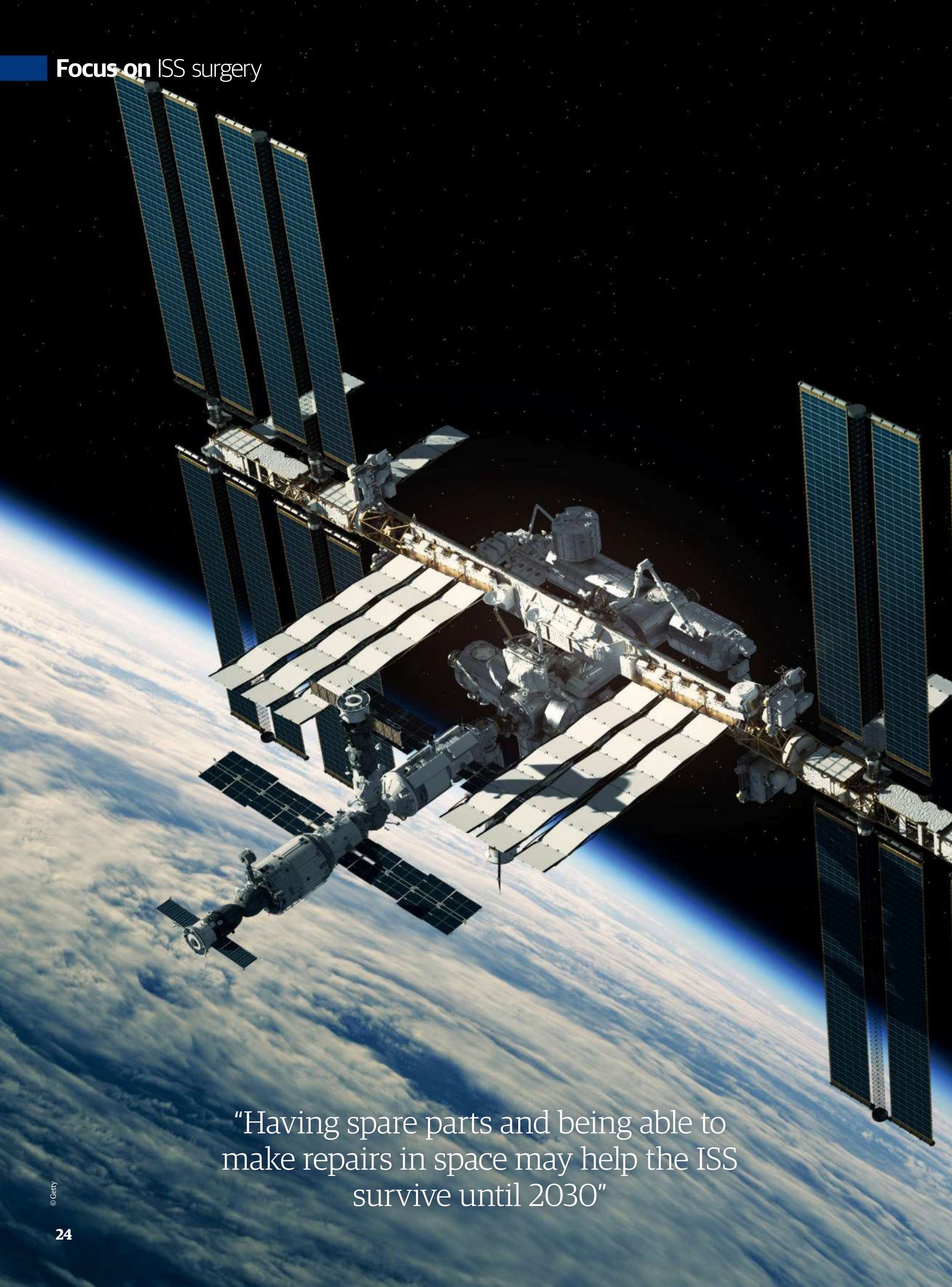
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“Having spare parts and being able to make repairs in space may help the ISS survive until 2030”

STATION GETS 'OPEN-HEART SURGERY'

The ISS computers get new life after an on-board circuit board transplant

Reported by Doris Elin Urrutia

Russian and European engineers have confirmed the success of their 'open-heart surgery' on the computer lifeline of the International Space Station (ISS). Teams from both the Russian space agency Roscosmos and the European Space Agency (ESA) developed a method in which an astronaut or cosmonaut aboard the space lab could upgrade the computers that keep the ISS on track and in the right position, known collectively as the Data Management System. It's a task that ESA representatives described in a statement as "the equivalent of open-heart surgery on Earth!"

Engineers rigorously planned and tested the process before it would be performed in space to ensure that the repair work could be done on-site without posing any risk to the spacecraft or its inhabitants, according to the ESA.

This type of testing largely happens behind the scenes, the ESA said, and doesn't usually get a lot of attention unless something bad occurs. But streamlining repair work can have implications for destinations that space agencies like NASA are aiming towards, like the Moon, Mars and perhaps beyond.

Anything in low-Earth orbit is already quite far away from the resources needed for repairs. Fixing a space computer is complicated because of the long turnaround. Time adds up as a computer waits to hitch a ride back to Earth, gets fixed and waits to launch again. The new procedure reduced repair time from six months to a few days, according to the ESA.

The recent development in space-lab computer repair was made possible by engineers' discovery that most of the failures in these computers took place in their circuit boards. The teams then came up with a solution, creating a new printed circuit board that matched the old version's form and function but relied on newer components easier to source.

In January, Russian cosmonauts confirmed that the computer from the surgery experiment survived the operation, in which astronauts replaced an older circuit board with a new one.

Having spare parts and being able to make repairs in space may help the ISS survive until 2030 and offers valuable information for other orbital projects. One such project NASA is targeting is the Lunar Gateway, which would orbit the Moon and serve as a hub for scientists and crew as they prepare to explore Earth's natural satellite. "Maintenance on the ISS demonstrates the experience and design knowledge needed to support future missions while ensuring more sustainable operations - a win-win," wrote ESA representatives.

Below: The new repair procedure meant the computer could be repaired while still in orbit



© ESA

WFFA

22 THINGS YOU DID

Earth's sister planet is an intriguing and mysterious world, with more to it than meets the eye

Written by Lee Cavendish

1 VENUS HAS A RICH HISTORY

Studies of Venus can be traced back to the ancient Babylonians in 1600 BCE. They tracked the movement of several planets and stars. The oldest astronomical document on record is a Babylonian diary of Venus appearances over a 21-year period. Venus played a serious part in the mythology of ancient civilisations, including the Mayans and Greeks. The name 'Venus' comes from the Roman goddess of love and beauty.

WHAT YOU DON'T KNOW ABOUT

2 THE PRESSURE'S ON!

Walking around Venus would be an unbearable experience for several reasons, but one of them is the extreme pressures on the surface. The atmosphere creates air pressure that is over 90 times the air pressure on Earth, which is similar to the pressure around a kilometre (0.6 miles) deep in the ocean.

Atmosphere

96.5 per cent of Venus' atmosphere is carbon dioxide, with the remainder being nitrogen, sulphur dioxide, argon and traces of water vapour, carbon monoxide, helium and more.

Crust

Venus' crust is made of silicate rocks, and is estimated to be 50 kilometres (31 miles) thick.

Molten mantle

The heat from the core creates a molten mantle that is 3,000-kilometres (1,200-miles) thick.

Metallic core

Venus' iron core consists of a solid inner and liquid outer core roughly 3,200 kilometres (2,000 miles) in radius.



3 IT'S JUST LIKE OUR EARTH

When looking purely at the physical parameters of Venus, it is remarkably similar to Earth. They are both almost the same in size and density, their compositions are similar and they both appear to have relatively young surfaces that are surrounded by an atmosphere with clouds. It's worth stating that Venus' clouds are primarily sulphuric acid though, which isn't something that you'd want raining down on you!

4 IT HAS MANY PHASES

Venus experiences different phases, just like the Moon. As Venus travels around the Sun within the orbit of Earth, it changes between a 'morning star' and 'evening star' roughly every nine-and-a-half months. During this period it shifts between different percentages of illumination, a trait that everyone normally associates with the Moon.

5 TRANSITS ARE VERY RARE

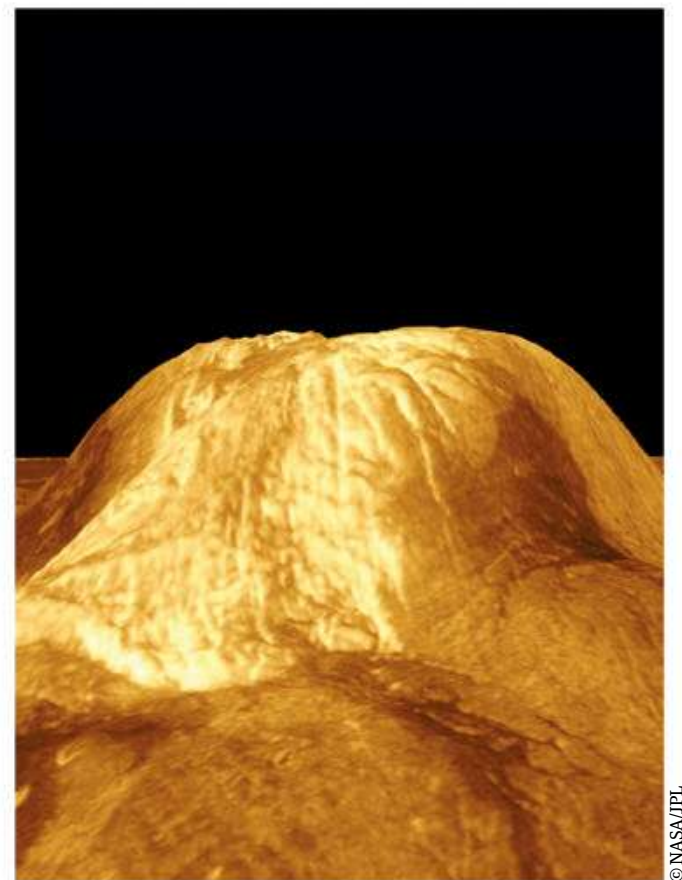
Venus is one of two planets that orbit the Sun within the orbital path of Earth. Along with Mercury, these two planets can find themselves between Earth and the Sun, sometimes creating a silhouette that moves across the Sun over a period of hours. These journeys are known as 'transits', and Venus is known to transit in pairs, with over a century separating the pairs, making it a very rare event.

6 IT'S HELLISHLY HOT

Venus is the hottest planet in the Solar System, even hotter than the dayside of Mercury, which has temperatures of 427 degrees Celsius (801 degrees Fahrenheit). Because of Venus' thick, carbon dioxide-rich atmosphere, the heat is efficiently retained, creating surface temperatures higher than 470 degrees Celsius (880 degrees Fahrenheit).

7 VENUSIAN VOLCANICITY

To add to the hellish image of Venus, it also has the most volcanoes present on the surface of all planets in the Solar System. On Earth there are 1,500 known active volcanoes, and Mars is best known for the largest volcano in the Solar System, Olympus Mons. However, Venus has over 1,600 known major volcanoes, and that's not including the smaller ones or any that haven't been detected yet.



© NASA/JPL

8 WHY IT DOESN'T HAVE A MOON

Venus and Mercury are the only planets in our Solar System that do not have their own moon. It's a bit more understandable as to why Mercury doesn't have a moon, because its close proximity to the Sun has a negative effect on any contenders, and it is even smaller than some known moons such as Jupiter's Ganymede and Saturn's Titan. However, researchers have argued that the reason Venus doesn't have a moon isn't as simplistic. There are two theories: the first is that any moon that Venus had was stolen by the Sun's gravity. The second is known as the 'double-impact theory', which states that a large celestial body hit Venus billions of years ago and created a moon, in a similar way to how Earth got its lunar companion. But several million years later, an even bigger object hit Venus, causing the retrograde rotation, weakening the tidal forces and sending the moon to sink into Venus, never to be seen again.



9 EARTH VS VENUS

What are the similarities and differences between the second and third planet from the Sun

The Sun

On Venus, the Sun would appear no more than a dimly glowing patch through the thick clouds and everlasting overcast weather.

Clouds

Venus is enveloped in clouds, not allowing any nosey astronomers to investigate the surface. While the Earth is also hidden by clouds, much more of our planet's surface is visible from space.

Surface rocks

Based on past exploration missions, the surface of Venus contains rocks of different shades of grey, carving out valleys and giving birth to mountains, similar to Earth.

Volcanoes

Both planets contain at least 1,500 active and dormant volcanoes on the surface.

10 A PERFECT WORLD FOR FUTURISTIC SPACECRAFT

There are advantages to scrutinising Venus from its clouds

Faster exploration

Due to superrotation in the upper atmosphere, which completes one rotation 60-times quicker than the surface below, this would allow for a rapid exploration of Venus.

The power of the Sun

Solar panels would be extremely useful, as Venus gets 190 per cent more sunlight than Earth.

Easier to explore from up high

There are more favourable conditions in the clouds, with much more bearable temperatures and pressures.

Improved capabilities

With improved lightweight technologies and controlled aerial mobility, aircraft on Venus is now a more likely proposal than it was in the 1960s.

Removing obstacles

In constant flight in the Venusian sky, this eliminates the need to navigate around harmful terrain and the planet's many volcanoes.

Head in the clouds

There has been discussion about whether it would be possible to create a colony in the clouds of Venus, much like Cloud City on Bespin in the movie franchise *Star Wars*.

“Conditions on Venus that would be favourable for life could exist in the clouds”

11 LIFE IN THE CLOUDS

Contrary to what the previous facts have strongly suggested, researchers have proposed that life could be found on Venus - just not on the surface. A study by Sanjay Limaye of the University of Wisconsin-Madison's Space Science and Engineering Center suggested that microbial life could be present in the cloud tops.

Microbial life on Earth has been found at altitudes of 41 kilometres (25 miles), and these researchers have said that conditions on Venus that would be favourable for life could exist in the clouds at altitudes of 48 to 51 kilometres (30 to 32 miles). Here, temperatures would be roughly 60 degrees Celsius (140 degrees Fahrenheit) and

12 A DAY FEELS LIKE A YEAR

On Venus, that is very much the case. One Venusian day, which is one complete rotation on its axis, takes 243 Earth days, making it the longest day of any other planet in the Solar System. Even a year on Venus is shorter, as it takes 224.7 Earth days to complete one revolution around the Sun.

13 'BACKWARDS' ROTATION

Another trait that makes Venus different to most of the planets in the Solar System is its rotation. The usual routine for planets is to spin anti-clockwise on their axis, but Venus is an oddball and flaunts a clockwise rotation. The leading theory as to why Venus and Uranus have what is known as a 'retrograde rotation' is that they were smacked by large objects early in their history. This collision left the planet seeing stars and spinning the wrong way.

14 WHAT THE FUTURE HOLDS

Researchers want to understand every planet in the Solar System. Efforts in the late-20th century showed that Venus is a difficult planet to observe remotely from the surface, but with new technologies and a better understanding comes innovative exploration ideas. A lot of these new ideas have a common theme, which is exploring Venus from within the clouds. As Venus has more favourable conditions in the clouds, with wind speeds that allow an object to travel around the planet much faster than it rotates, scientists are looking to introduce aircraft or airships. By utilising solar and wind power, and the added help of buoyancy, robotic missions could become a feature of Venus in the foreseeable future.

Seen from above

These irregular, patchy filament-like structures were observed by the ESA's Venus Express spacecraft, more specifically its Visible and Infrared Thermal Imaging Spectrometer (VIRTIS).

Stationary waves

Scientists have found stationary waves, or 'gravity waves', in the nightside's atmosphere that do not move in the same way as the planet's superrotation.

Indirect surface observations

These stationary waves come from steep, mountainous areas on Venus that send waves through the atmosphere and reach the upper atmosphere. These stationary waves are useful in telling scientists what the planet's topography is like.

Never-ending heat

The extremely slow rotation and a tilt of just 3.39 degrees ensures that the planet stays continuously boiling for extended periods of time.

The mystery of the nightside

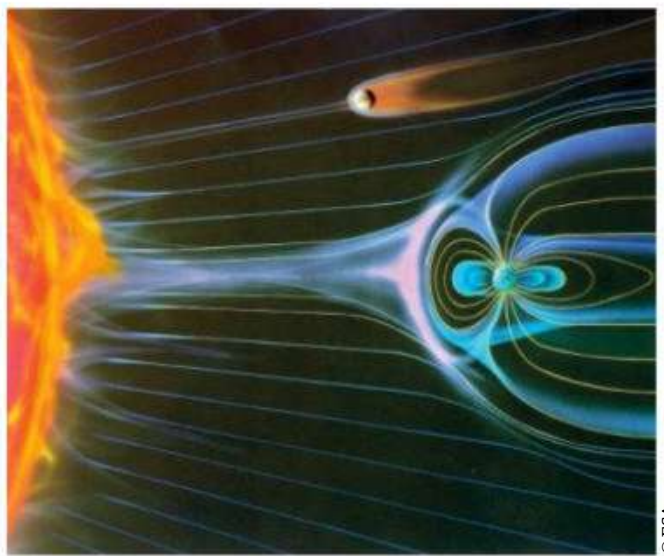
On the nightside the upper clouds form into different shapes and morphologies, causing a more irregular system.

15 REWINDING THE CLOCK

Venus wasn't much different from Earth once upon a time, and could have even supported life. 700 million years ago, Venus suffered dramatic changes in its climate that saw it bulk up its atmosphere in a process known as a 'runaway greenhouse effect'. Before the runaway greenhouse effect took over, it is believed that Venus had a reasonable atmosphere and could have harboured liquid water for about 2 or 3 billion years. Before carbon dioxide dominated the atmosphere and made it too hot and dense, it is possible that Venus had an environment that could have supported life for billions of years.

16 LOSS OF A MAGNETIC FEELING

Although it is often referred to as Earth's twin, something that differentiates the two planets deep down to their cores is that Venus creates a negligible magnetic field. Planetary scientists believe that Venus has an iron core that is a similar size to Earth's. However, due to the sluggish rotation of Venus, consequently reducing the motion of the planet's core, this weakens the planet's magnetic field, or magnetosphere.



17 IT HAS HAD MANY SPACECRAFT VISITORS

Before attention turned to the exploration of Mars and other planets in the Solar System, Venus was the target that space agencies wanted to send their robotic missions to. This genesis of interplanetary exploration began with a lot of spacecraft and launch failures, starting with the Soviet Union's Tyazhely Sputnik in February 1961.

The first craft to aim for Venus experienced a launch failure, and there have since been 41 other missions launched with the intention to explore the planet. Of these missions, over 20 have been successful, and the first of these to conduct a successful planetary encounter was NASA's Mariner 2 space probe on 14 December 1962.

18 CASE OF THE MISSING LIGHTNING

There are electrical pulses bursting through the heavy atmosphere, but the missions that have gone to Venus to find them have made it an even more confusing endeavour. Ground-based telescopes and space probes - including NASA's Cassini, the European Space Agency's Venus Express and the Japan Aerospace Exploration Agency's (JAXA) Akatsuki missions - have had nothing more than some subtle hints about the presence of Venusian lightning. Researchers believe it could still be present, but it is just much more localised and more rare, which is why there has been no definitive evidence yet. Or it could be the case that there isn't lightning at all.

19 SOVIET SUCCESS AT VENUS

The Russian Space Agency, Roscosmos, is not particularly well known for its robotic exploration missions in recent years, as its missions are now few and far between. Before the dissolution of the Soviet Union in 1991, the country was prominent in Venus exploration missions in the 1970s and 1980s. One historic mission that the Soviets conducted was Venera 7 in December 1970, which became the first mission to land on a different planet. Then, in March 1982, the Venera 13 lander managed to survive Venus' extreme temperatures and pressures for over an astonishing two hours.



20 ONE OF THE BRIGHTEST IN THE SKY

Because Venus is in such close proximity to Earth, it is the third-brightest celestial object in the night sky, sitting behind the Sun and the Moon. The Latin nickname for Venus, which is largely unused in modern days, is 'Lucifer', which translates to 'light bringer'. Lucifer is also a name for the Devil, which is quite a coincidence considering the hellish conditions on the surface of Venus.

21 A SOURCE OF SHADOWS

Because Venus is the third-brightest object in the night sky, it is bright enough to cast shadows on the surface of Earth. Only two other celestial objects are capable of this: the Sun and the Moon. However, very good eyesight is needed to see these Venusian shadows.

22 VENUS' WEIRD WINDS

Although the planet moves slowly, the clouds move across the atmosphere once every four Earth days; this is known as 'superrotation'. This generates speeds of 360 kilometres (224 miles) per hour, which surpasses the speeds of the most dangerous hurricanes on Earth. The speeds decrease with cloud height, creating winds that are just a few miles per hour on the surface.

INTERVIEW BIO

Professor Didier Queloz

Didier Queloz discovered 51 Pegasi b as a PhD student at the University of Geneva, Switzerland. Now he is a professor at the Cavendish Laboratory at the University of Cambridge. He also won the Wolf Prize in Physics in 2017.

Professor Michel Mayor

Michel Mayor is professor emeritus at the University of Geneva's Department of Astronomy. He has been at the University of Geneva and the Observatory of Geneva since 1971 in several positions. He retired from his position as professor in 2007.

Above:
An artist's
impression of
51 Pegasi b and
its host star,
which
is 50 light
years away
from Earth

© ESO

DIDIER QUELOZ & MICHEL MAYOR

WINNERS OF THE NOBEL PRIZE IN PHYSICS 2019

All About Space sits down with two of the three recent Nobel Prize laureates to talk about what it was like to win the prestigious award, how their discovery has had profound ripples in the exciting field of exoplanet research and why this is only the start...

Reported by Lee Cavendish

First of all, congratulations on winning the 2019 Nobel Prize in Physics. For those who don't know the story already, could you please give us a brief recap of the discovery of 51 Pegasi b? What were your intentions going into the research? How did you feel when you made the discovery?

MM: Yes, it [exoplanet research] was a very hot topic in the last part of the 21st century, but few people were really working on it. It was only a very small number of people working on the domain at the time. Nevertheless, we started with our French colleague from Marseille and Haute-Provence Observatory. We started building a new kind of spectrograph with a much higher sensitivity precision and so on.

We started at the end of the 1980s, and in 1993 or 1994 it was ready to measure. And we asked for observing time, because it was not automatic. We got about one week every two months to measure solar-type star selection - 142 stars - and we were very surprised that we got the first hint of an exoplanet at the end of 1994. This was actually a big surprise, because the theory at the time for the formation of giant planets - like Jupiter and so on - was its period should be larger than ten years. It was not a small discrepancy because 51 Peg's orbit is only four days. It was a discrepancy by a factor of a thousand.

I decided to postpone the announcement for the next season. In July 1995, with Didier, we started to remeasure the same star to check if the period was present with exactly the same period, with the same amplitude and the same traits. This was a check to eliminate any uncertainty.

Right: An illustration of Queloz and Mayor, two of the winners of this year's prestigious award



We then decided to publish the paper in *Nature* at the end of August, and then there is the review procedure. It was potentially a hot topic, and so *Nature* asked for not only two referees, but three.

In the meantime, I was going to announce the discovery at a meeting in Florence, Italy. It was a huge, very important meeting with something like 300 colleagues, all interested in solar-mass stars. It was a good place to discuss this, but I asked if anybody had some comments, because I was still slightly anxious that the interpretation was not a good one. I received a message from HR saying, "No. We are not allowed to speak [about the discovery] because of the embargo policy of *Nature*."

We already had a lot of journalists and Italian television crews there because the rumours were

spreading around. This was the start of this huge media interest.

DQ: At that time there were no exoplanets, so the main difficulty that we had to deal with was first to convince ourselves that indeed it was a planet. This is because it didn't fit, at all, the picture that you would expect for finding another Jupiter. Most of the article was about dealing with that and making sure that this was real. And then it was to make sure we had comprehensive evidence that it could not be something else.

When we could reach the final decision that it must be a planet, either way we came up with this amazing situation that was almost apologising when we announced the object. [We said that] we

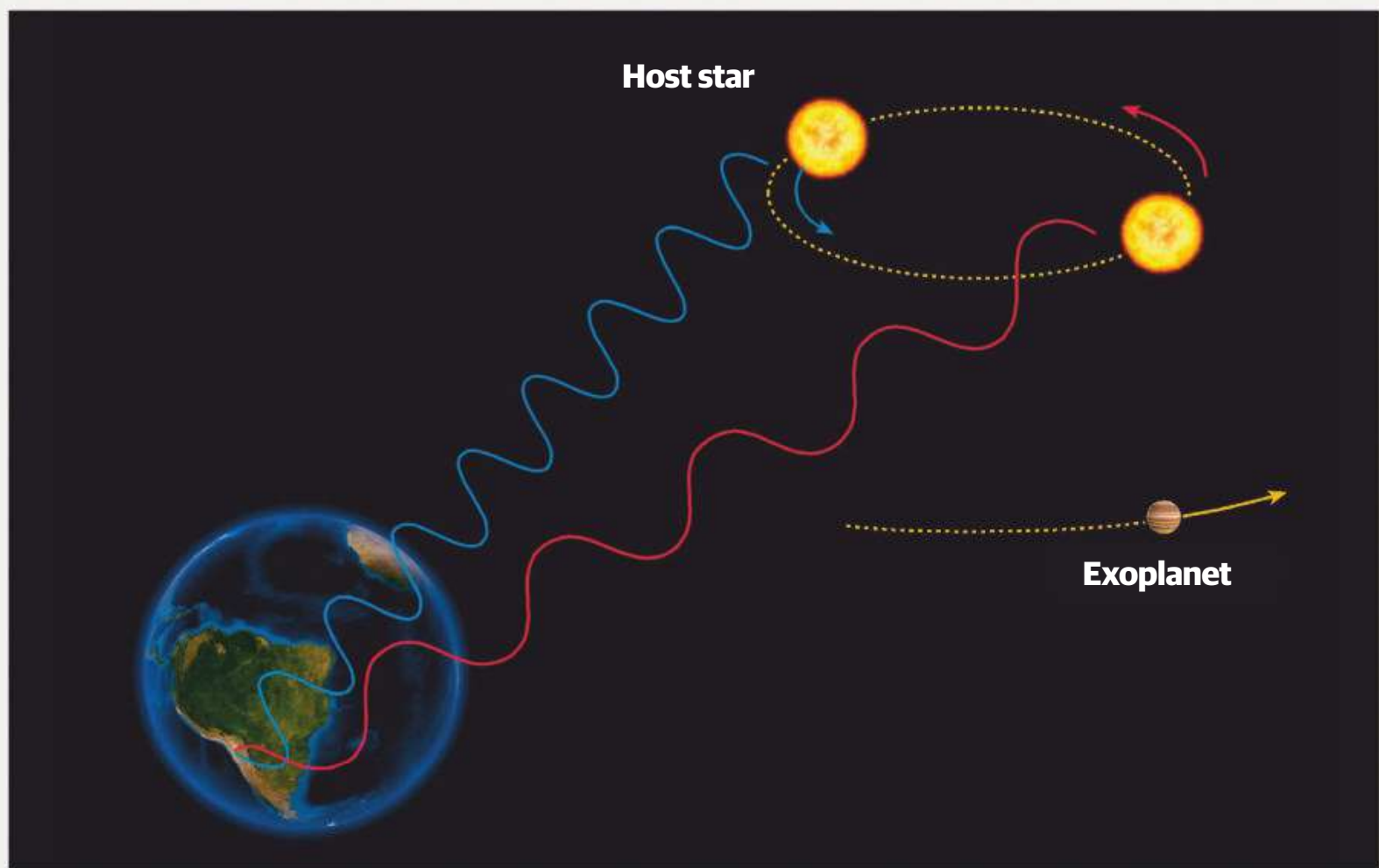
The story behind the discovery

In October 1995, a PhD student called Didier Queloz and his doctoral advisor Michel Mayor discovered the first-ever exoplanet orbiting a solar-type star within the Milky Way. The object, named 51 Pegasi b (51 Peg), was discovered to be a Jupiter-sized exoplanet orbiting its host star so closely that it only took four days to complete one revolution.

This discovery was made using a custom-designed spectrograph at the Haute-Provence Observatory in southern France. This spectrograph allowed them to observe the spectrum of the star. If a certain wavelength had seemed to move towards the blue or red end of the spectrum – referred to as the Doppler effect – then this could be interpreted as a gravitational wobble caused by an exoplanet.

There is now also the transit method of detection, which involves monitoring the brightness of a star and watching out for a dip in its brightness caused by an exoplanet's transit between Earth and the distant star.

Over 20 years later and over 4,000 exoplanets have been discovered within the Milky Way, each seemingly different from the last. This variety of exoplanets, which includes planet types not seen within our Solar System such as hot Jupiters, sub-Neptunes, super-Earths and others, has led to exoplanet study gaining much attention.



“It was kind of a rough time I must say, because we were really facing huge scepticism for some time” **Didier Quelot**

Above: The radial velocity method of exoplanet detection was used to discover 51 Pegasi b

Right: Queloz provided the Nobel Prize Museum with the key that was used to enter the Haute-Provence Observatory during their studies

Far right: Probing atmospheres is key to finding an Earth-like exoplanet

can't find any other explanation but [the 51 Peg signal] being a planet, while being aware that the planet is weird, because it's a hot Jupiter – it doesn't exist in theory. It wasn't predicted at all.

That was mostly the mood at the time, and you can imagine the community reacted to that with a lot of scepticism because it was the first exoplanet, which was something that people were used to having been announced in the past and proven wrong. It was kind of a rough time I must say, because we were really facing huge scepticism for some time.

What were you doing when you found out you had won the Nobel Prize?

MM: When I received the announcement, in fact I was not receiving any telephone calls before. It was by chance I connected myself [to the internet] just before leaving San Sebastián to the airport. I connected myself to the site of the Nobel, and it was at a good moment when they did the announcement in Stockholm, and the first sentence I heard was, “This year it will be devoted to people having contributed to the knowledge of the cosmos.”

It was great. And then after a few minutes I was obliged to leave to go to the airport, so it was a little bit stressful. I was then contacted at the bus station to have a short interview with the Nobel Foundation, but it was awfully noisy, so it was

completely impossible. I asked them to do a second call when I will be waiting for the plane at San Sebastián airport. It was okay. It was really nice, but a bit stressful.

DQ: Well, I was absolutely caught by surprise, because I was in the middle of a meeting. I didn't even realise that was the day of the announcement, and finally I got a phone call from the university, from the PR office. After the announcement, they were telling me, “Are you aware that you just won the Nobel Prize?”

I couldn't believe it. It took me some time to realise, and then I got 20 peaceful minutes. This was because I was with a team which was a scientific meeting for another project, and after the PR team came up and took care of me, I got dragged down to London and was in front of a crew of journalists. There were so many people and so many cameras. It was quite an amazing time. It did not seem very real, actually. [Laughs]

How does it feel to be in the same bracket as physicists such as Albert Einstein, Niels Bohr, Richard Feynman and so on?

MM: It is very impressive because in some sense, we cannot compare ourselves to these people. But I realised suddenly that what we did had a very huge impact for the field. It's probably the reason why we have been chosen for this huge prize.

DQ: We received a lot of messages from friends and colleagues working in the same field, and everybody is really super excited because it is acknowledging 24 years of work on a new field. When you look back, what has happened in the last 24 years, it's just amazing. There are so many people and results from this field. And now we are finding out the atmospheres of planets. I mean, we are measuring the wind on some of them.

I think it's reflecting not only the impact of the first discovery, it's also reflecting the huge impact of a community working in this field, and you feel this complete shift in the paradigm of where we sit in terms of solar systems - especially when we compare ourselves to other systems in the universe. In a way we have been very useful, which is good. I'm very pleased that the community is thrilled.

Do you think this is the first Nobel Prize win of what could be many for exoplanetary research?

DQ: Yeah, I really believe so, because, again, this is a new field. We've just kick-started it. I mean, you have to imagine right now that there are thousands of people working in this field, and I really hope that having this one acknowledging the field, there will be way more awards. Not only the Nobel Prize, but other awards for other pieces of work. And you can just think ahead a little bit and ask yourself, 'What about when are we going to find some evidence for life?' I mean that would obviously be another Nobel Prize. You can imagine that between

that kind of discovery and the first one, there may be some other aspect that has had a huge impact on the field.

In a way, I'm glad that now the field is clearly acknowledged by physicists as a main field of astrophysics, because this is a reality. We have to now recognise the fact that there is a new field of extremely active research that attracts a lot of students right now, with so much to find and so many big surprises to unravel.

There are plenty of upcoming missions to be very excited about. NASA launched the TESS mission just last year. The European Space Agency is going to launch the CHEOPS satellite soon and there's also going to be the James Webb Space Telescope in 2021. How close do you think we are to finding Earth 2.0?

MM: I will mention first the CHEOPS mission. It's a mission like TESS, but with a slightly different focus, and then after you will have, for example, [the ESA's] PLATO mission. This will be a very ambitious mission that will be launched in 2026. You have plenty of missions to be developing for the future, and already today, as you mentioned, TESS is publishing a lot of interesting topics, and we are quite interested in this mission. This is because TESS provides the size of an exoplanet, but you don't have the mass. What we are doing is to do Doppler measurements to get the mass. If you have the mass and the size, you can start to see - based on its density - if it is a rocky exoplanet or a

gaseous exoplanet. Determining the physical state of a planet is a completely new field, due to the combination of these two techniques.

DQ: Well first, I'm not very comfortable with the concept of Earth 2.0, because it implies a lot of stuff. I mean, we really specify here something that would be like the Earth, which means not only talking about a planet that would have one Earth mass and one Earth radius, you're also talking about a planet that has similar plate tectonics, a similar atmosphere and similar evolution. We are very far away from doing that right now, because we don't have the equipment to be able to say that an exoplanet is really like the Earth.

But the key message is, we're working on it. There are a lot of ongoing programmes that are probing the question of 'what is a 'rocky planet?'' We're learning, because there are many kinds of rocky planets, as mentioned by Michel, that we are finding with TESS.

Now, the next stage is we have what I call 'Earth-like', which is that they look like the Earth. In that sense, Venus looks like the Earth as well. It's about the same kind of orbit, it's got the same kind of mass and the same kind of size.

And then there will be some space missions that are going to get something about the atmosphere on some of the systems that look a bit like the Earth, like the TRAPPIST-1 system, for example. This is something that's going to happen in the next ten years mostly, thanks to the James Webb Space



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Interview Didier Queloz and Michel Mayor

Telescope, or other ground-based telescopes such as the Extremely Large Telescope of the ESO.

MM: Presently, the instrumentation to detect the precise velocities with new instrumentation is extremely precise. This is not the difficulty. Presently, one of the most important difficulties is the magnetic activity of our star. When you say you are measuring the velocity of a star, and to detect the small wobble due to the planet, you have to take a mean [measurement] of all the velocity of atomic spaces in front of us. If you have magnetic activity, we're not objective. This is really a limitation to detect very small planets like the Earth. You have to remember that the wobble induced by the Earth on the Sun is only something like eight centimetres per second. It's so small and the stars are not really helping us.

William Borucki, the principal investigator of the Kepler mission, had a lot of adversity in trying to get the mission started and had a lot of setbacks. Did you have any similar sort of adversity in your research of exoplanets, or was it not taken seriously enough by people?

DQ: I'm not sure that's the reason why he had difficulty. I mean, the concept of not being taken seriously. I think the idea of looking for planets around other stars was serious business at the time. The problem was not the question, it was whether there was some hope to detect anything. I think the problem that Bill Borucki had at that time was to demonstrate that statistically it would be meaningful to do this programme for two reasons.

First, I mean, nobody had carried out the performance that they had in mind. You need to talk what we call ten parts-per-million accuracy, which is something that nobody had achieved before. And I think he had to do quite a lot of benchmarking to demonstrate that just a detector could reach this. The other problem they had, and in a way we helped him on that aspect, is if you don't have a mass, then you realise that finding an Earth is very statistically difficult. This is because it's very rare to get the transit. And actually, if you really think about it, detecting an Earth, the Kepler mission has entirely failed on this, because they have not found any. The reason why Kepler decided to go ahead is because we demonstrated that there are plenty of other kinds of planets.

I think that's kind of the paradox of the field. I think the field was helped by the paradox of the fact that there are actually, in the entire universe, plenty of other kinds of planets that are very easy to pick up by the transit. If you count today how many planets are known around other stars, most of these detections have been found by their transit, because they are short-period planets.

That's an interesting aspect of it, to realise that the Kepler mission was granted the 'go ahead' very shortly after the first transiting planet was found. I think Borucki got the mission to go ahead because some people suspected that there will be all these kinds of planets as well, and the mission will detect them.

Sometimes science goes in a strange way, and there's something that I learned recently. It is something that a lot of people mentioned, some other Nobel Prize winners, which is the gambling aspect of a successful discovery. You know, in a way Bill Borucki is a gambler, because he bet on the number that never appeared, but he got a lot of money out of the other numbers that he found.

MM: The first people having really made the most precise measurements to search for exoplanets were two Canadian people, Gordon Walker and Bruce Campbell. It was very interesting to see that they were using the 3.6-metre (11.8-foot) telescope in Hawaii, as it was only able to obtain six to eight nights. So you see, it was extremely difficult to get measurements on that because this kind of programme was not considered a top priority. After, it changed completely, and I believe we never faced real difficulties of this kind.

"Kepler decided to go ahead because we demonstrated that there are plenty of other kinds of planets" **Didier Queloz**

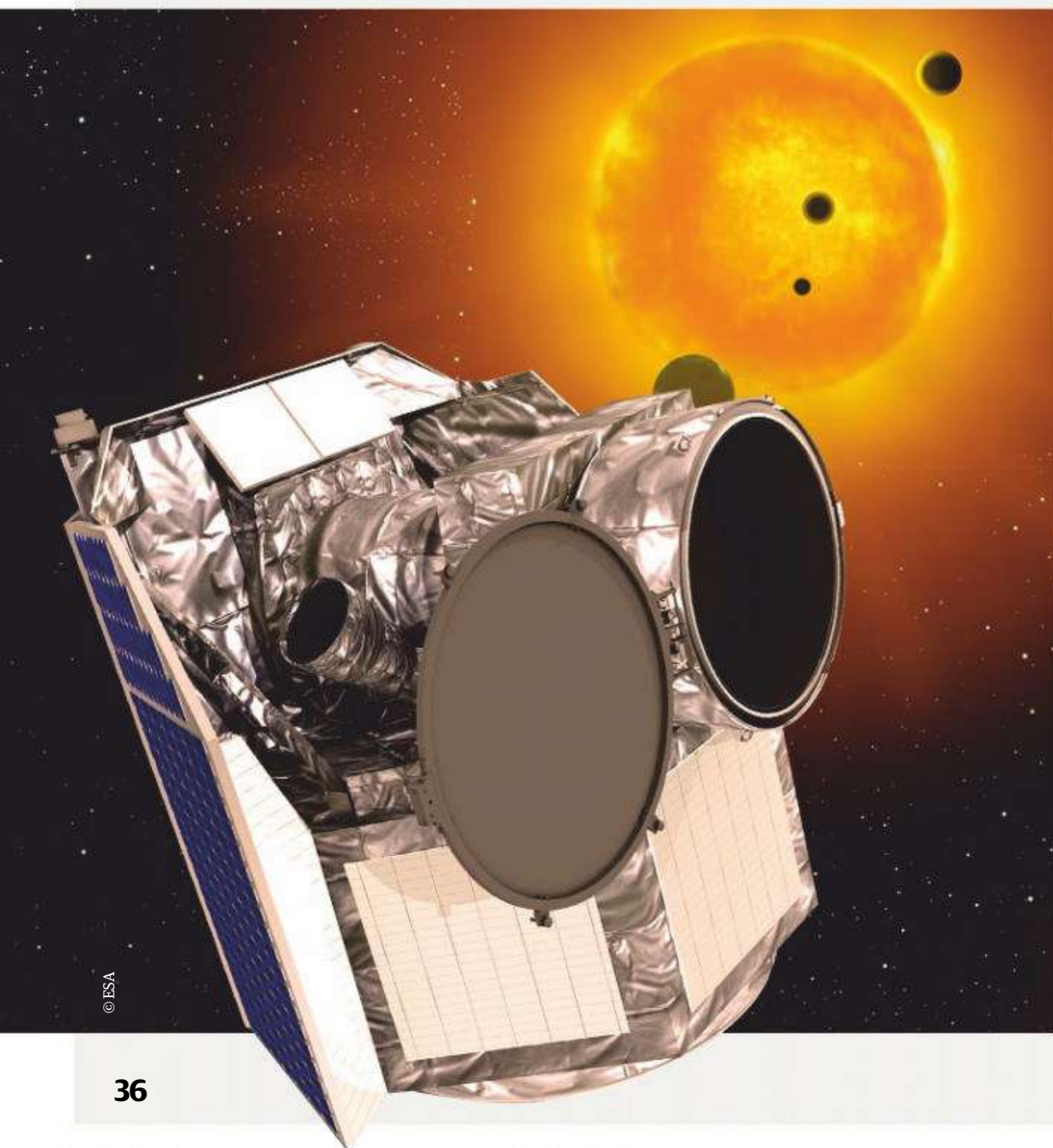
Left: Queloz is chairman for the science team behind the ESA's CHEOPS mission

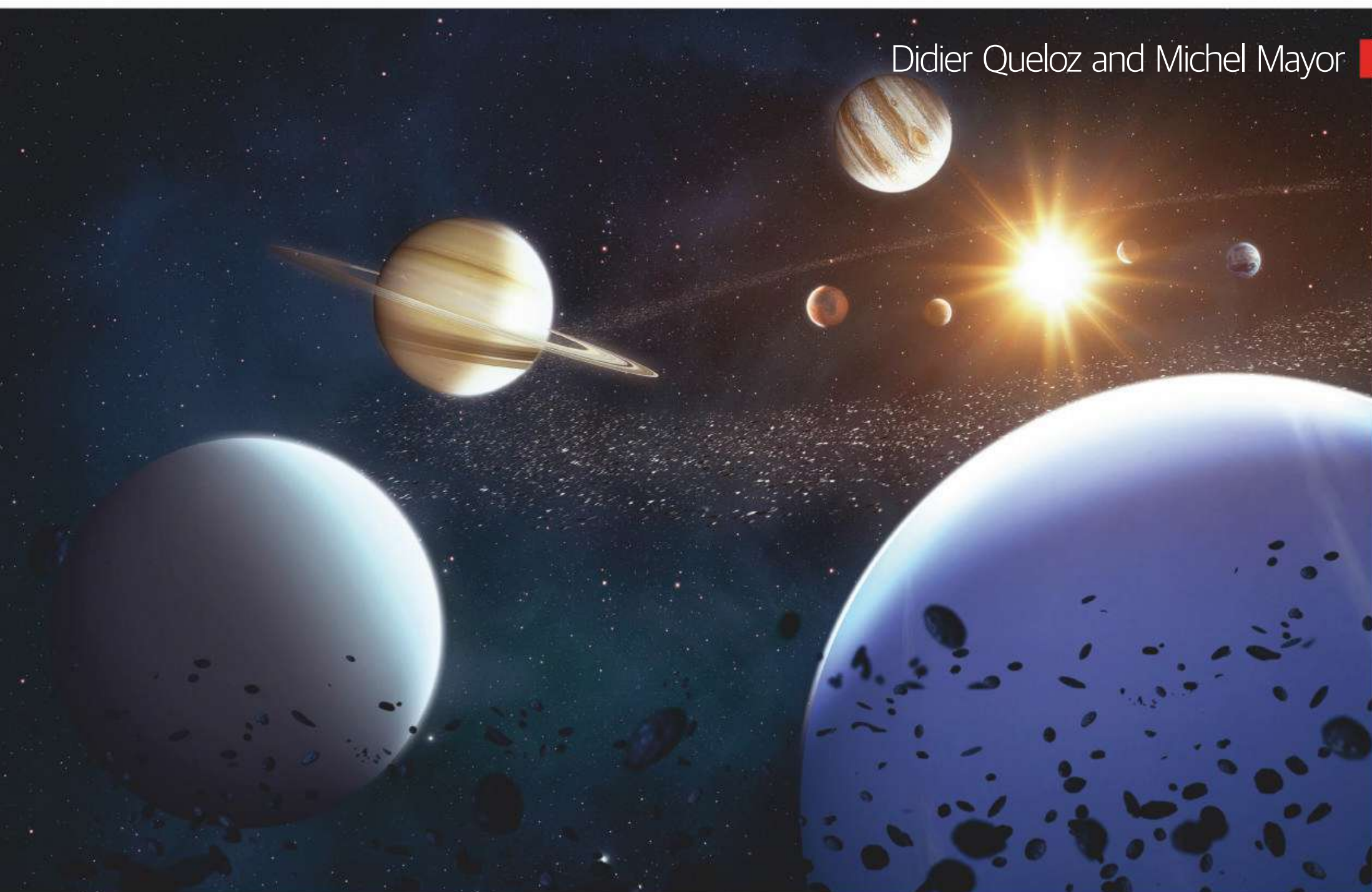
Right (top): Understanding other planetary systems has consequently changed our understanding of how our Solar System evolved

Right (bottom): Mayor present at the Nobel Prize Museum in Stockholm, Sweden

Your discovery of a Jupiter-sized planet that only takes four days to orbit its star is something unimaginable if we thought about it in the context of our own Solar System. How do you think your discovery changed our understanding of planetary formation, and how can we apply that to the formation of our own Solar System?

MM: It's a very good question because it is important to remember that the reason for this kind of short-period planet was only existing as an interpretation. In the 1980s there was a paper by Peter Goldreich and Scott Tremaine announcing a theory that was discovered, later called 'orbital migration'. If you have a young planet embedded in a disc of dust and gas, we have a very strong phenomena creating the migration of the planet towards the star, and it is explicitly written in the abstract that Jupiter was not born where it is today. But apparently no observer carefully read this paper, because the main focus of this paper was devoted to galaxy engulfment. When you have a small galaxy like one of the Magellanic Clouds and it is touching the Milky Way, it would be suffering exactly the same phenomena.





In fact the understanding of the short period of 51 Peg, it was already existing 15 years before. But nobody realised. Afterwards there were several papers by many other people having continuously studied this kind of problem, but it's very strange that nobody basically said, "Maybe it would be best to try and find this short-period object." And it's only after the discovery of 51 Peg people published a paper showing the link between these two kinds of approach.

DQ: That is the best summary by Michel. But it's clear that the reason before and after [the discovery of 51 Peg], where people were seeing planetary formation from a different angle. I mean it's always the same. You don't have to throw the theory away in the trash. But there was a really big missing piece. An interesting aspect which people are trying to explore right now is, what about the Solar System itself?

Shortly after the discovery of 51 Peg, people were starting to think about how maybe the Solar System has changed as well. People then came up with theories such as the 'grand tack' or 'late heavy bombardment' where there has been a restructure of the Solar System due to motions at the time of the formation of the system. I think that the concept right now, which is the system has moved around from its initial position, is fully accepted, and it was definitely 51 Peg that enforced this concept into the theory.

MM: After a few years, just after the discovery of 51 Peg, it was a very important discovery for the diversity of systems. It has huge diversity with extremely short periods, strange organisation of the distances of planets and extremely elongated orbits. A lot of complexity was found compared to what we have in the Solar System.

Are there any missions or projects coming up that you will be keeping a very keen eye on in the field of exoplanetary research?

DQ: A project I was very keen to establish - which took me quite a long time to convince agencies and people to join in on - is to design what's called an experiment to find an 'Earth twin'. This is to build state-of-the-art equipment and then to dedicate a telescope for ten years to probe a limited number of stars. This is called the 'Terra Hunting Experiment'. That's something I was keen to start when I moved to Cambridge, and I created a dream team of people and universities around this project.

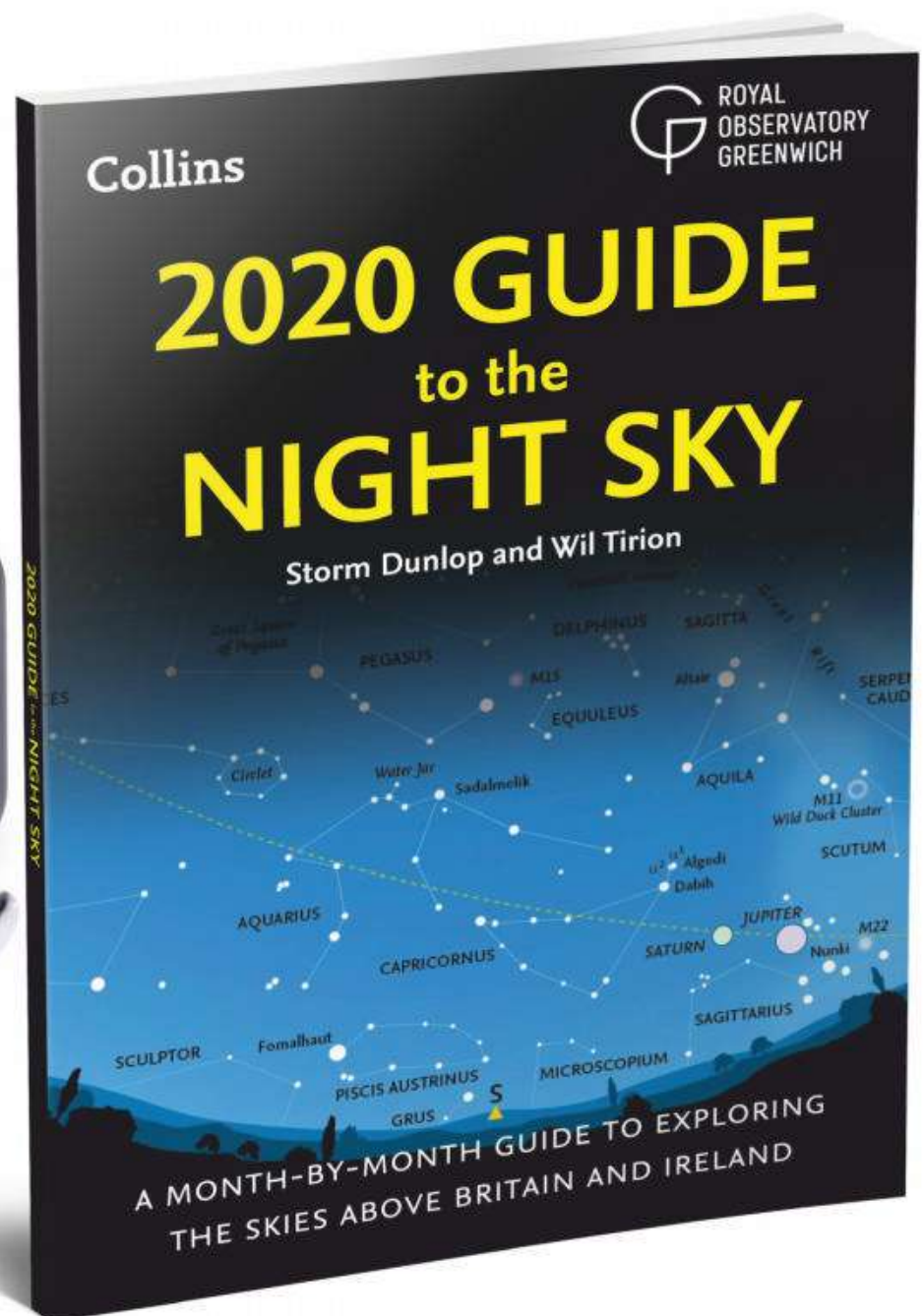
Now, of course, there are a lot of other big programmes that exist for which there is a lot of excitement around. One of them is the launch of the James Webb Space Telescope, because that will be a game changer in terms of the analysis and the study of an exoplanet's atmosphere. As well there will be the Extremely Large Telescope, when there will be a high-resolution spectrograph on it. And of course there is CHEOPS, which will be launched soon, and I'm very, very excited.



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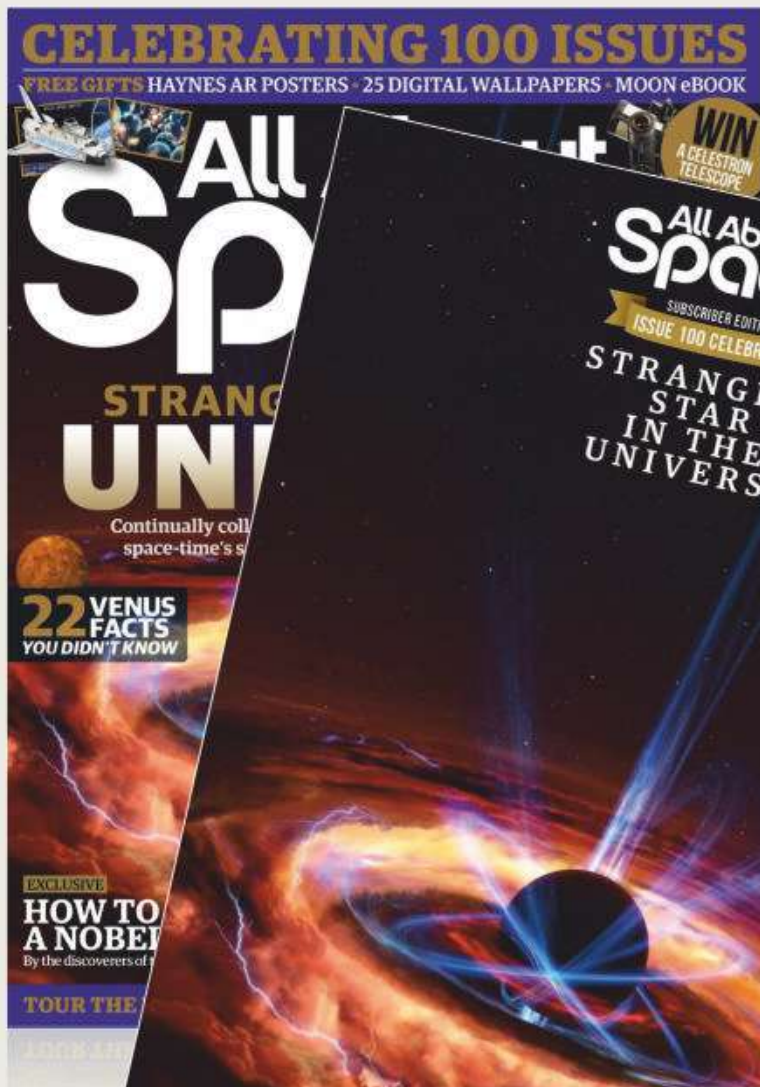


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THE FUTURE OF SPACE DEBRIS

Orbits around Earth are becoming dangerously overcrowded, but the space community is taking action...

Reported by Richard Edwards

Accident report: close encounters

Fēngyún-1C vs missile

An entirely intentional collision, this 2007 Chinese anti-satellite test added over 2,800 trackable objects to the US Space Surveillance Network catalogue – a 25 per cent increase at the time.

Iridium vs Cosmos

An Iridium satellite was destroyed in February 2009 in a collision with Russian satellite Cosmos-2251. NASA said it was the first time that two functioning spacecraft had accidentally collided with each other.

ISS vs satellite

The International Space Station's July 2015 near miss with a fragment from an old Russian weather satellite was so dangerous that the three astronauts on board moved to the escape capsules.

Aeolus vs Starlink

In September 2019, the ESA's Aeolus, a satellite studying wind patterns on Earth, had to make evasive manoeuvres after a near miss with one of Space X's newly launched Starlink satellites.

Cosmos vs Genesis II

Another Russian Cosmos satellite dating back to 1981 had a close call in September 2019 when it flew close by Bigelow Aerospace's Genesis II – a prototype habitat launched in 2007.

4

October 1957 became one of the most important dates in space exploration when the Soviet Union successfully launched Sputnik. It was the day

the Space Age officially began, but an otherwise glorious technological achievement brought with it an unfortunate consequence – the mission left behind the first space debris in history.

Over the last six decades space traffic has increased massively. That's inevitably meant that the volume of space debris – defined as non-functioning human-made objects either in Earth orbit or re-entering the atmosphere – has grown with it. It's the problematic downside of our expanding ambitions in space.

The desirable low-Earth orbits – altitudes up to around 2,000 kilometres (1,243 miles) – are the most crowded areas and are only going to get busier as more countries and private companies vie for a foothold in the final frontier. There are over 8,400 tonnes of human-made material orbiting our planet. That includes well over 100 million individual pieces of debris, and while the vast majority are less than a centimetre in diameter, some 900,000 pieces are in the one to ten centimetre (0.4 to four inch) range, and 34,000 are larger. There are also several thousand defunct satellites.

"Space is big and we took it for granted, especially early in the space programme when we were launching so few things so infrequently," says Laura Forczyk, founder of Atlanta-based space analysis

and consulting firm Astralytical. "But now we have things like mega-constellations going up we have to look at space in an entirely new light."

"[The idea that space was 'out of sight, out of mind'] was certainly the notion in the beginning of the Space Age," adds Holger Krag, head of the European Space Agency's Space Debris Office. "However, since the 1990s there has been sufficient awareness in the international community, and debris prevention measures have been defined jointly. The problem of space debris is, today, well understood, and I don't think any space-faring nations would still tend to ignore it."

Space debris isn't simply an environmental problem. It's a very real threat to any spacecraft operating in orbit, as all those rogue objects travelling at speeds of 27,400 kilometres (17,000 miles) per hour or more can lead to serious damage, and the more that's up there, the greater the chance of some kind of catastrophic collision. While not every impact is going to cause the sort of cataclysmic damage that gave Sandra Bullock a very bad time in the 2013 film *Gravity*, all that floating junk is a clear and present danger. Indeed, colliding with an object of just one-millimetre diameter has the potential to destroy a satellite's subsystems, something one-centimetre (0.4-inches) across will probably disable a spacecraft and a ten-centimetre (four-inch) body could be a full-on satellite killer with the potential to cause it to disintegrate. Imagine the ramifications of that happening to a

Below:
This debris-shielding test shows the damage caused by a 7.5mm object travelling at 7km/s



© ESA

crucial GPS or communications satellite and it's easy to see why we can't simply stick our heads in the sand and pretend it's not an issue, especially as the space debris problem would get worse even if every government and company operating in orbit decided to cease operations tomorrow. "We have passed a tipping point in the sense that the number of artificial objects in orbit will grow even without further human influence," explains Krag. "This is because the self-production [of additional debris] in orbit due to collisions and the resulting fragments supersedes the 'sink', which is the natural decay [of satellites falling into the atmosphere]."

It's an inconvenient truth that space debris has the potential to create more space debris. While most of the material in orbit originated as a satellite, a mission payload or as discarded sections of a launch vehicle, further collisions can cause these to break up into smaller particles - some 65 per cent of the space debris objects that have been catalogued originated from the break-up of larger bodies.

This isn't something that's taken us by surprise - as far back as 1978, NASA's Donald Kessler proposed the idea of so-called 'Kessler syndrome', a scenario where low-Earth orbits become so densely packed with material that it creates a cascade of collisions, with one impact leading to another, to another and so on. When that happens the quantity of rogue bodies floating in space increases exponentially, and the region becomes unsustainable for future spacecraft operations. When it comes to fixing the problem for future missions, however, prevention may be better than a cure...

"The main factor [in dealing with space debris] is our future behaviour," Krag points out, "and the degree to which we manage to implement debris prevention successfully. Today we find debris-prevention measures in international standards and also in many national space laws. They are applied in practically every new space mission."

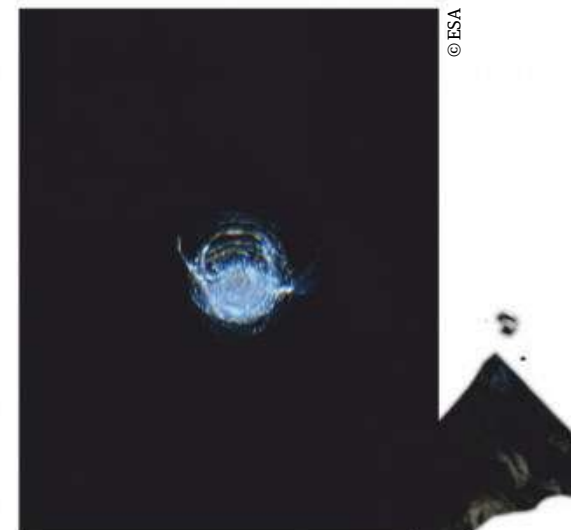
This means that rather than merely focusing on clearing up the mess that's already in orbit - though that is on the agenda - we need to minimise the amount of new debris we create. That places the responsibility on operators to manage their satellites into a safe retirement. For example, it's now recommended that satellites in low-Earth orbit be directed to burn up safely in the Earth's atmosphere within 25 years of the completion of their mission. It's also important that a defunct spacecraft's energy reserves, be it fuel or batteries, are run down to reduce the risk of explosions that create new debris.

Krag says, however, that there is some distance between the theory and the reality: "The success rate in applying [these prevention measures] is not satisfactory at all. Only about half of the missions in the most critical [orbital] regions manage to implement them so far. The reason for this is technical reliability and a tendency to operate spacecraft too long, with the risk of losing them before debris-prevention action is implemented."

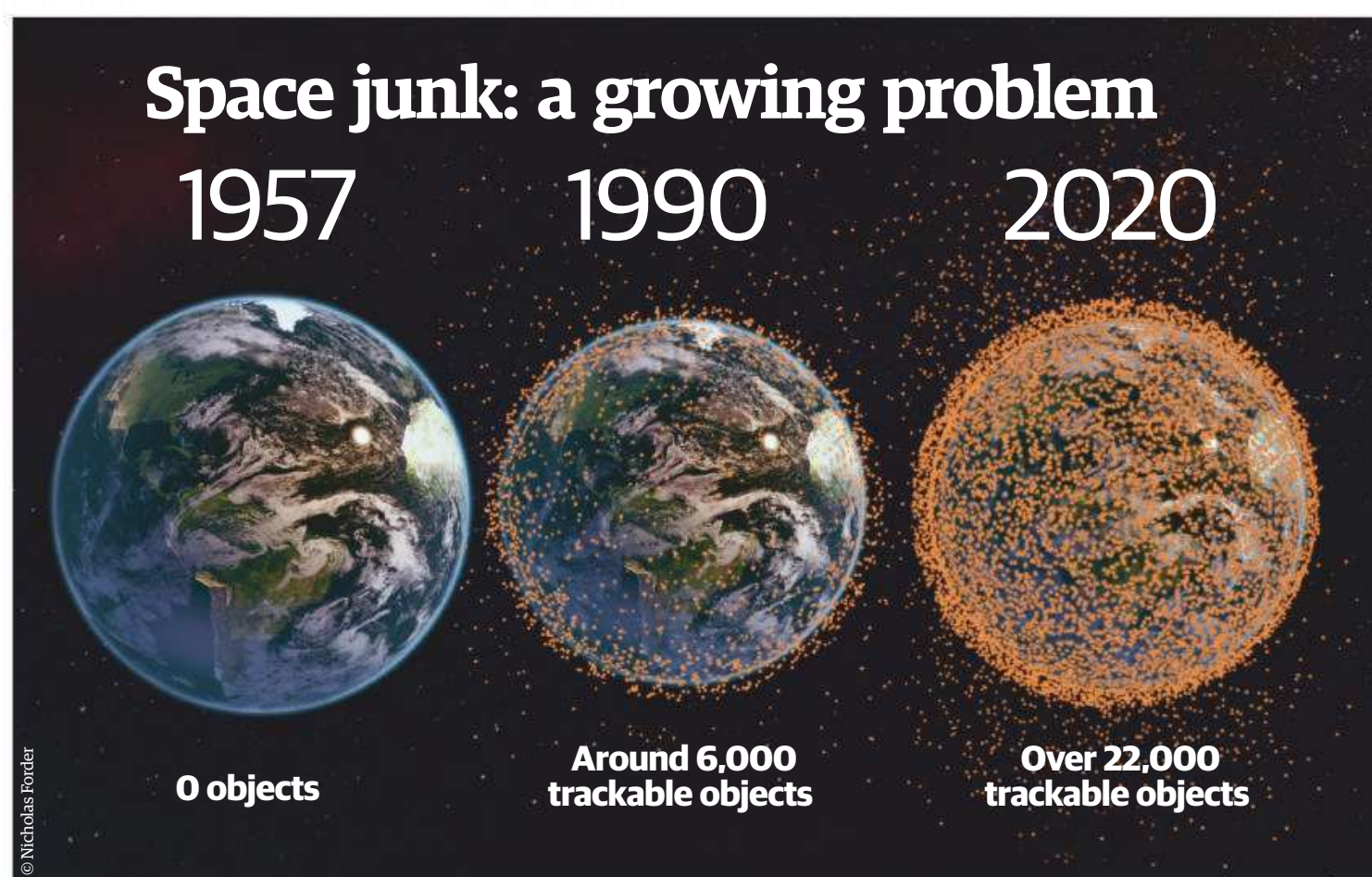
Right: The Sentinel-1A satellite's solar array before and after a collision with a millimetre-diameter particle

Below left: Donald Kessler, the NASA scientist who came up with so-called 'Kessler syndrome' in 1978

Below right: Tim Peake was glad this ISS window was quadruple glazed after impacting with a tiny piece of space debris



"Space is big and we took it for granted, especially early in the space programme when launching so few things" **Laura Forczyk**





Left: An artist's impression of spacecraft CleanSpace One

Below: Part of the debris shield of the ISS's Alpha Magnetic Spectrometer drifts into space

"The number of artificial objects in orbit will grow even without further human influence" **Holger Krag**

"We need to be much better, because with a success rate of 99 per cent, we could absorb even more space traffic. The problem is not the traffic itself, but the success rate in implementing prevention measures."

While Krag argues that these prevention measures are cheaper than Active Debris Removal, such clean-up operations still have a part to play. "We need to actively clean up space debris," he says. "This should target large and critical objects that have a high pollution potential. If done systematically we can reverse the trend."

That's easier said than done, however, because retrieving space debris is a complex problem even before you start to tackle the engineering. For starters, it's not immediately clear whose responsibility any clean-up operation is. In fact, the Outer Space Treaty of 1967 stipulates that any material placed into orbit remains the responsibility of the country who put it there - whether it's fully functional and intact or reduced to debris.

"There's the geopolitical problem where if it's a satellite that belongs to a certain government, then they need to give permission [for you to do anything], so you can't just go up there and remove anything," says Forczyk. "You need to have permission to remove it."

"Ideally we'd have an international space law that recalls the agreed debris prevention measures and an independent body that controls the implementation," adds Krag. "Such an international

treaty is not in sight, but spacefarers are reasonable and are about to implement such measures in national laws. If these laws are as far as possible harmonised, the same effect can be achieved."

Once you've navigated the politics, there are numerous practical and physical issues facing anyone who wants to remove debris from space - not least the fact that we're not entirely sure what's up there. The US Space Surveillance Network is responsible for tracking objects in orbit, and its information is supported by data collected by radar and telescopes operated by other international agencies. We can also get an idea of the concentration of smaller debris particles invisible from Earth by studying the outer surfaces of craft brought back from space. It's an inexact science, however, especially as we don't even have data on all the active satellites up there.

"We don't necessarily have the best data on the satellites that are still up there working, simply because we don't have the means and the agreements to globally track them," explains Forczyk. "The US Space Surveillance Network track this, but it doesn't have perfect information. There's the idea that maybe we need to put some kind of tracking technology on satellites, and there are companies working on that, but right now we actually do not have a very good idea where they all are, how many there are and the sizes and the movements - especially when it comes to military satellites. So even if you have a really good idea of

the mountain of space debris and the inactive space junk, you still haven't got a good idea of all the active satellites." And however accurate our view of what's out there, not every satellite is equipped to do anything with the data.

"The International Space Station can manoeuvre around a problem," says Forczyk, "but if it's some small satellite then they probably don't have the propellant to manoeuvre. Weight and energy equals money, so if you're adding systems you'll add to the cost of the satellite and the launch. Most of the time nearby space debris is not a problem for a satellite, it's just a close call, but you just never know."

Various debris-removal projects are already at various stages of development. RemoveDEBRIS, led by a team from the University of Surrey, launched in 2018, and its experimental technologies for capturing debris include a net, a harpoon and a drag sail to pull the craft into Earth's atmosphere to burn up safely. Japan-based Astroscale and the American Rocket Lab also have missions in the pipeline.

"The current technology that is being tested or proposed for clearing up space debris is not cheap, and hasn't really been tested yet," says Forczyk. "The prices are still very high because launch, the cost of hardware and the cost of operations are expensive. And who foots that bill? Is it going to be countries that decide that it's in their best interest to pay for space-debris removal, or is it going to be companies that somehow can benefit from it, maybe by recycling the material, or recycling even hardware itself, somehow bringing it back down to be safely reused. That's the big question."

"I think that until we start seeing people lose assets, governments are going to care less," she continues. "People who work in the industry, they care. The people who track the debris, they care, but when it comes to government officials, until they see it as a problem, they're going to be less inclined to come up with solutions or consider it a problem to be solved."

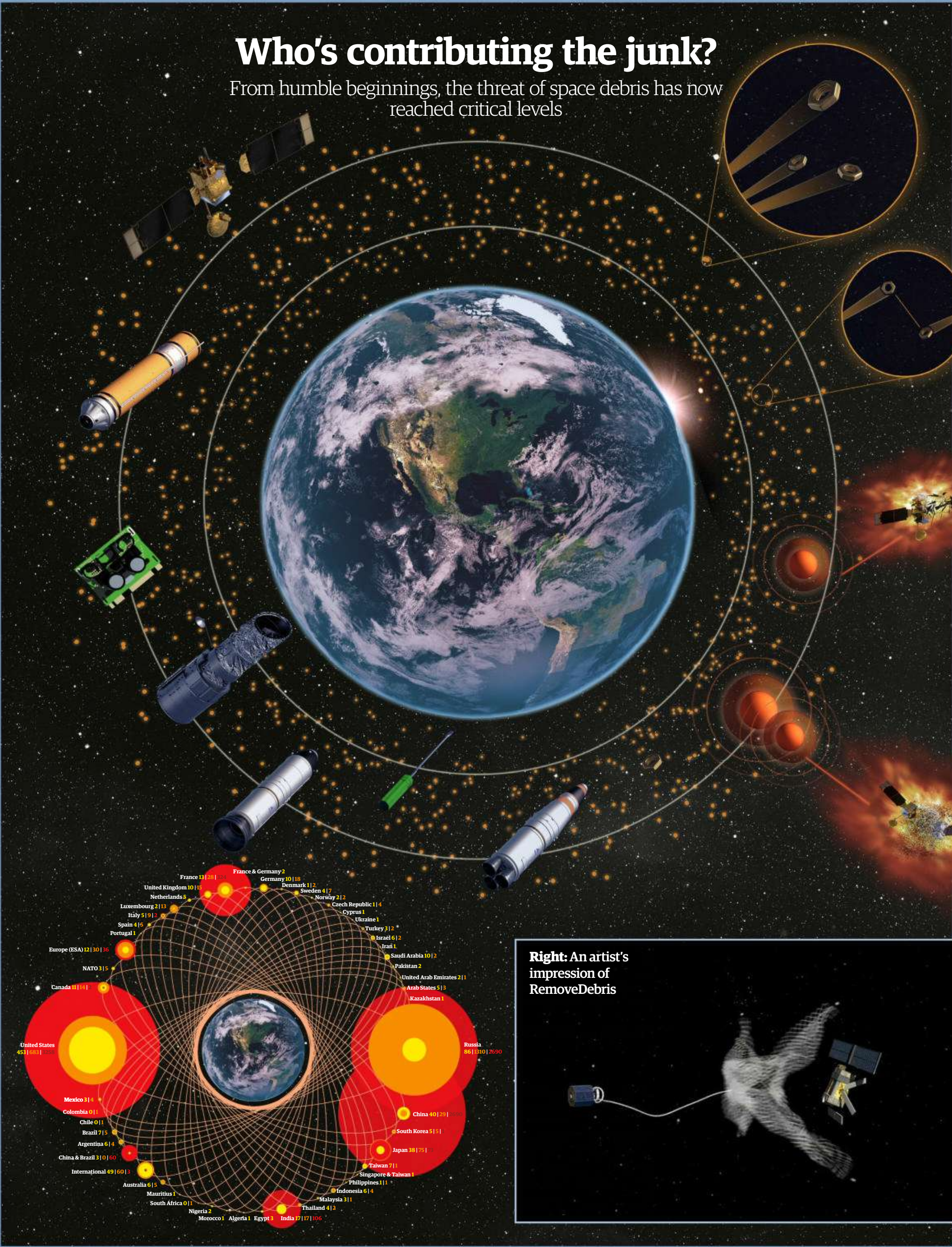
Ultimately, any successful technology has to be so reliable that it's not going to risk damaging the object being retrieved, creating more debris. "If you mess up you risk creating more space debris, and nobody wants that," says Forczyk. "Unsurprisingly, everyone is being very cautious about how they move forward!"



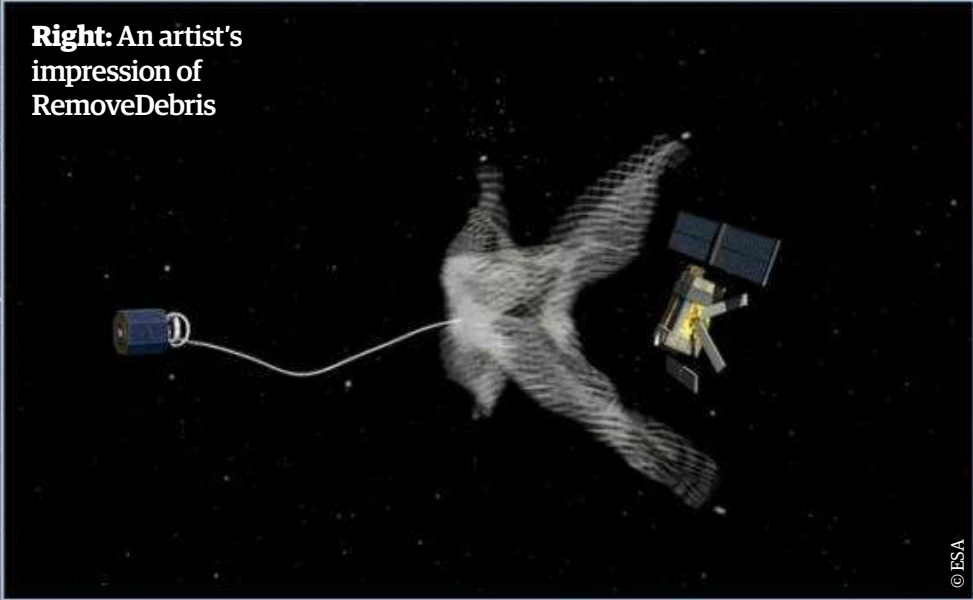
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Who's contributing the junk?

From humble beginnings, the threat of space debris has now reached critical levels



Right: An artist's impression of RemoveDebris



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WE ASKED PAST AND PRESENT TEAM MEMBERS... WHAT'S YOUR FAVOURITE MEMORY OF WORKING ON ALL ABOUT SPACE?



Launching the magazine



"When I was told we'd be launching a space magazine I was super excited, and I was thrilled to be asked to work on it! Getting it out of the door wasn't easy though. It was a lot of late nights, and a lot of takeaways. But when we finally had issue 1 in our hands, it was rather magical."

Jonathan O'Callaghan, Features Editor
(April 2012 – March 2014)

Meeting Brian May



"They say you should never meet your heroes, but on this occasion, Dr Brian May didn't disappoint. I interviewed him a few weeks before I left *All About Space* for Asteroid Day, which Brian was a patron of. I tried to keep on the topic of asteroids, but he didn't seem to mind when I slipped a question in about Queen. A total gent."

Ben Biggs, Editor (June 2013 – August 2015)

Exploring space through art



"It has to be being given the opportunity to work with such an array of talented artists for our covers and art throughout the issues. Space is a world I'm not all too familiar with, so it really opens the door for me to experience new things and get to look into things I otherwise wouldn't. I've had the chance to work with a selection of different artists whose areas of expertise lie in different parts of the art world, and each one you have to approach in a different way."

Jonathan Wells, Art Editor (August 2017 – Present)

I was able to pass the torch



"Because of my time with the team and magazine, I was able to have in-depth conversations with my stepson about the planets, constellations and what you can see on the Moon from Earth, as well as reassuring him that the supernova of the Sun won't happen for a long, long time. I have to add he could already recite all the planets when he was five!"

James Sheppard, Photographer
(January 2013 – June 2019)

Behind the scenes of Nat Geo's MARS



"A few months after joining *All About Space*, I was offered the opportunity to go to Budapest, Hungary, to be part of a press team to see the filming of National Geographic's *MARS*, season two. This was an unbelievable and eye-opening experience, getting a rare peek behind the curtain, and I am still bragging about it today!"

Lee Cavendish, Staff Writer (May 2017 – Present)



Exploring multiverse theory



"One of my favourite theories is the possibility that there could be universes beyond our own, and all of the paradoxes this throws up. Could there really be infinite universes? The very concept is mind-boggling. I look forward to the day we can somehow prove or disprove it."

Nikole Robinson, Production Editor & Freelance Writer (July 2017 – Present)



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We've been looking up at the Moon for millennia, but it was always just out of reach. Stories were made up about it, associating it with deities or speaking of a 'Man in the Moon' that watches over all. Others wondered what it would look like up close.

On 20 July 1969, man achieved what had previously been thought impossible: two astronauts landed on the surface of the Moon for the first time ever. More Moon landings followed in an era since dubbed the golden age of space exploration, but our curiosity is far from sated.

In this book of the Moon, find out what really happened when Neil Armstrong and Buzz Aldrin stepped outside their Lunar Module and uncover what is being done to preserve that moment in history before taking a tour of the craters and maria. Learn how to take the perfect photographs of our lunar neighbour, and discover what's really on the Moon's far side.

STAR PROFILE

The Sun

The Solar System would be nothing if it weren't for the power and influence of our nearest star

The Milky Way is home to billions of stars, and the universe is home to billions of galaxies. In the vast and infinite cosmos, our star - the Sun - has created a residential spot we call the Solar System. The Sun is the true centre of the Solar System: not only does everything else orbit around it, from asteroids to gas giants, but it makes up 99.8 per cent of the Solar System's mass and is 108 times the diameter of Earth.

This colossus was formed 4.6 billion years ago from a cloud of dust and gas. After this cloud began to rotate and collapse, it took 50 million years to form and become the star it is today. This was the point where the core of the star reached pressures and temperatures so intense that nuclear fusion was ignited. This ignition kick-started the formation of helium from hydrogen, releasing radiation in the process that provides Earth with light, warmth, power and so much more.

At the start of the Sun's life, planets and everything else in orbit were still forming from the leftover debris that began to fragment. The Sun has been in its mature state for nearly 5 billion years, and it will continue to be for another 5 billion years. After this point the hydrogen will run out, and the Sun will look to form heavier elements such as carbon, oxygen and so on. When this happens the radiation output will be greater than its gravity and it will swell into a red giant, swallowing Mercury and Venus and evaporating all the water and life on Earth. Afterwards the outer layers will be expelled into the cosmos, and what will be left is a white dwarf star.

Away from the doom of its distant future, the Sun is a marvellous protector and provider with an erratic and tempestuous side. It has several

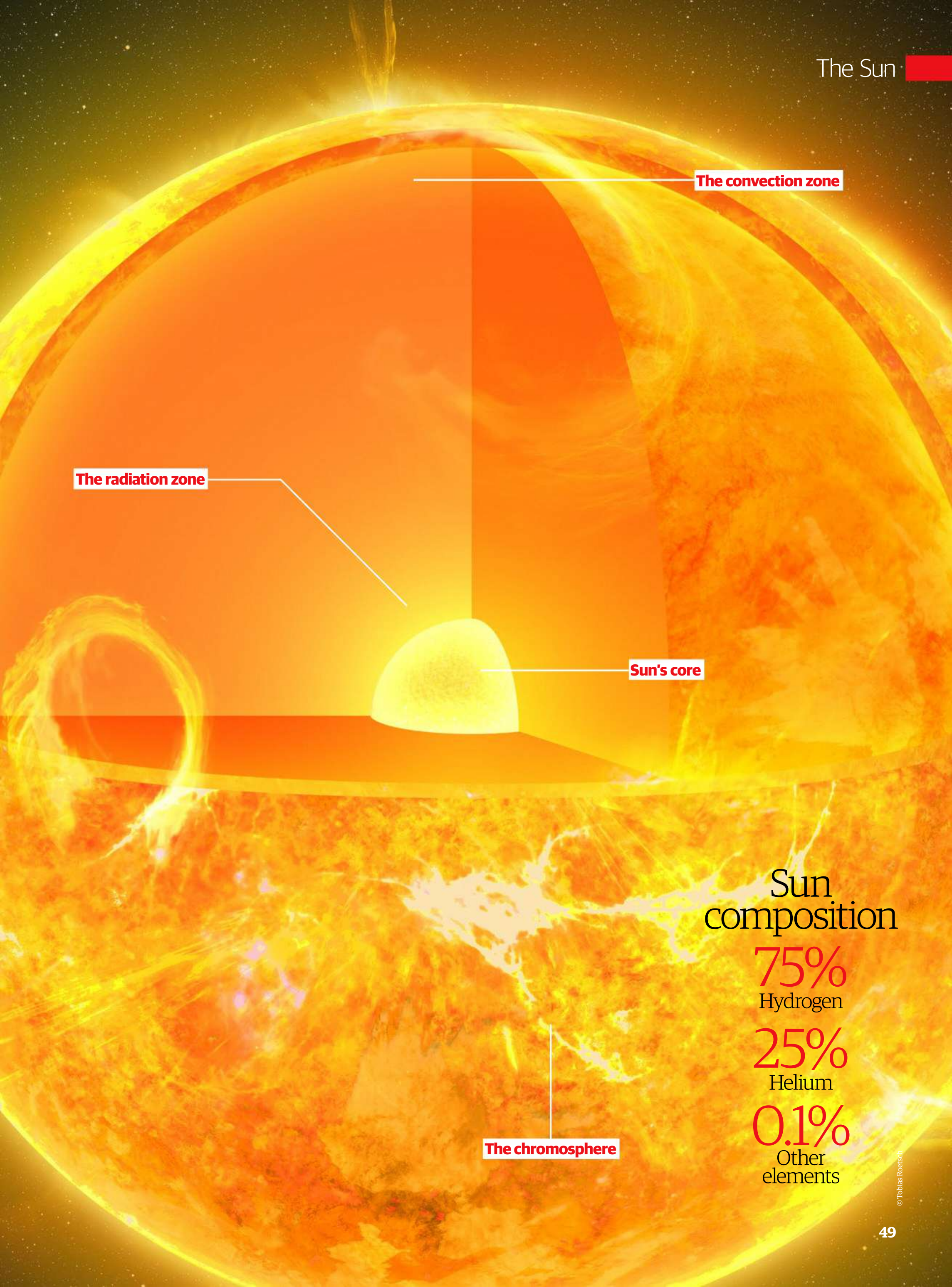
zones within its interior and atmosphere, starting with a core that burns at over 15 million degrees Celsius (27 million degrees Fahrenheit). This takes up roughly a quarter of the distance to the surface, and outside the core are the radiation and then the convection zones. The coldest layer of the Sun is the photosphere, the visible surface; this is between 6,125 and 4,125 degrees Celsius (11,000 and 7,460 degrees Fahrenheit). Next is the chromosphere and the mysterious corona, invisible without the aid of an eclipse. The corona's temperature ranges from 1 to 10 million degrees Celsius (1.7 to 17 million degrees Fahrenheit), and is perplexing to astronomers because it gets hotter the further away from the Sun you are. The smartest minds and the most well-kitted missions are yet to answer why, and future missions have put this phenomenon on their list of what we need to know about the Sun.

The intense activity of the Sun creates an equally intense magnetic field that permeates throughout the entire Solar System. Because the Sun is essentially a ball of plasma - matter consisting of ionised gas - and not a solid, it rotates at different speeds depending on its latitude. This unequal rotation causes kinks and twists in the magnetic field, creating sunspots and solar flares, which are usually accompanied by the expulsion of highly energetic particles in the form of solar wind and coronal mass ejections (CMEs). These particles provide Earth with its beautiful aurorae as they collide with the Earth's upper atmosphere, putting on a beautiful light show.

Coronal streamers

The corona

"The coldest layer of the Sun is the photosphere, the visible surface"



The radiation zone

The convection zone

Sun's core

The chromosphere

Sun composition

75%
Hydrogen

25%
Helium

0.1%
Other elements

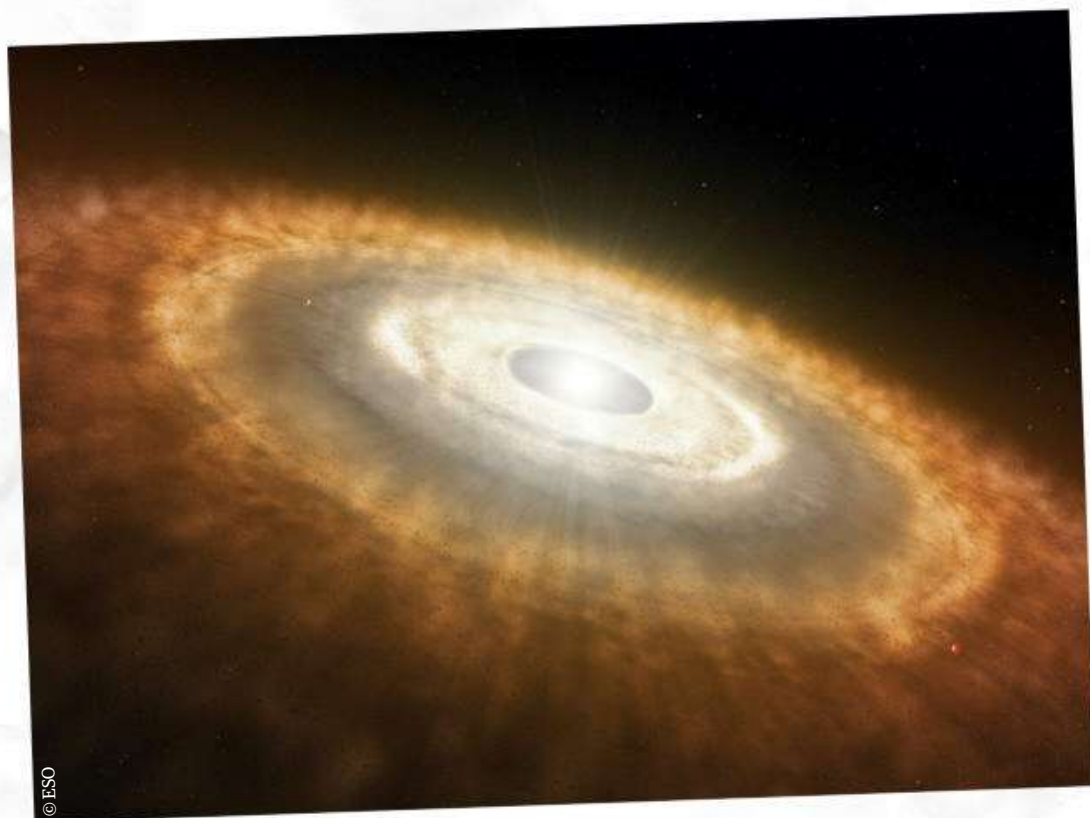
The latest news from the Sun

Studying the solar wind

Several scientific papers have recently been released to the public based on the data collected by NASA's Parker Solar Probe (PSP). One of the new announcements is just how complex the solar wind is. On Earth it is seen as a constant flow of plasma, but the PSP has been able to look much closer – well within the orbit of Mercury – and it has shown a much more complex and active system. The PSP's FIELDS instrument has found that there have been sudden reversals in the magnetic field and incredibly fast-moving jets of material occurring much closer to the Sun. Understanding this process is key in understanding how the solar wind is moving away from the Sun, especially with the momentum that makes it able to permeate our entire Solar System.

"The complexity was mind-blowing when we first started looking at the data," said Stuart Bale, the University of California, Berkeley, lead for the Parker Solar Probe's FIELDS instrument suite. "Now, I've gotten used to it. But when I show colleagues for the first time, they're just blown away."

"The complexity was mind-blowing when we first started looking at the data" **Stuart Bale**



What's happening to the dust?

You wouldn't have thought it, but dust is everywhere in space. After all, all asteroids, comets, planets and even the Sun stem from these cosmic crumbs. However, there is a dust-free zone close to the Sun, and the current theory behind this is that the great temperatures up close obliterate the dust – but this has never been proven.

Now, however, the PSP has shown undeniable evidence that this is the case. Its imaging instrument, WISPR, short for Wide-field Imager for Solar PRobe, has observed dust thinning at a distance of just over 11 million kilometres (7 million miles) from the Sun. The thinning effect continued to be observed as close as 6.4 million kilometres (4 million miles).

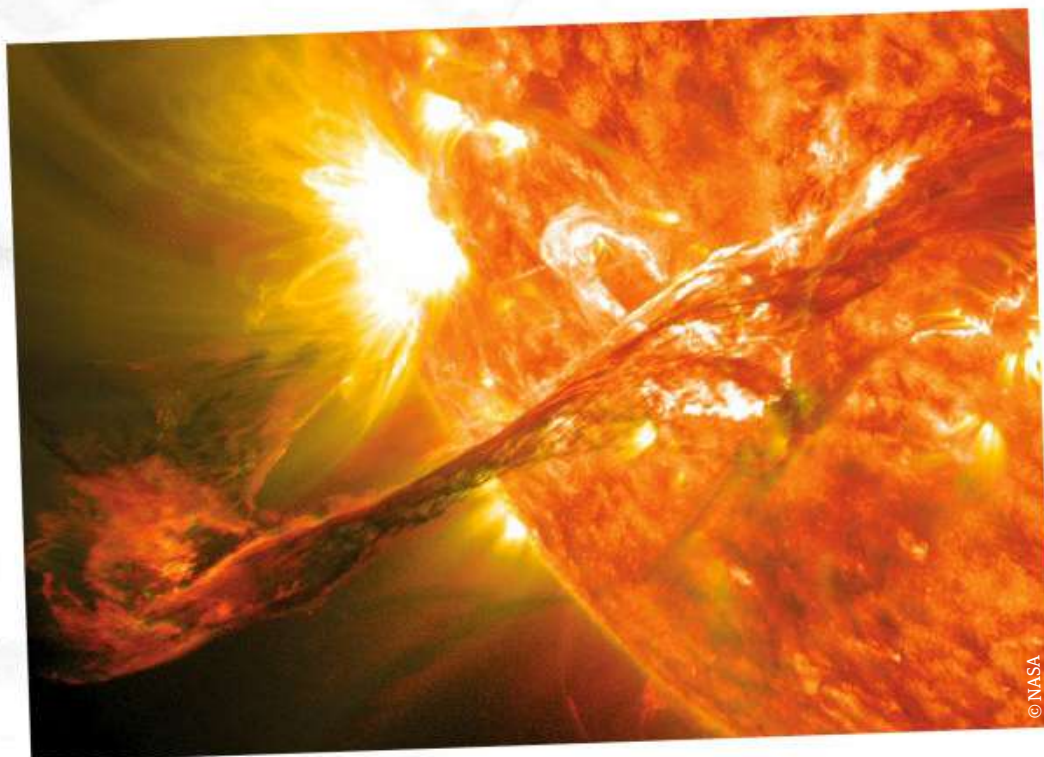
"This dust-free zone was predicted decades ago, but has never been seen before," said Russ Howard, principal investigator for the WISPR suite at the Naval Research Laboratory in Washington, D.C. "We are now seeing what's happening to the dust near the Sun."

At the rate of thinning measured by the PSP, the zone that would be completely devoid of dust would start at somewhere between 3 and 5 million kilometres (2 and 3 million miles) from the Sun. This means the probe could possibly see this on its sixth flyby of the Sun, which occurs in 2020.

Machine learning detects solar flares in real time

Solar flares are unpredictable and can be extremely aggressive, requiring around-the-clock observations. A host of satellites are keeping a keen eye on the Sun, and this produces data at a faster rate than it can be examined. Scientists at the Cooperative Institute for Research in Environmental Sciences (CIRES) and the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information have come up with a machine-learning technique to highlight significant changes in space weather.

"Being able to process solar data in real time is important because flares erupting on the Sun impact Earth over the course of minutes. These techniques provide a rapid, continuously updated overview of solar features and can point us to areas requiring more scrutiny," said Rob Steenburgh, a forecaster at the NOAA Space Weather Prediction Center (SWPC) in Boulder, Colorado. In order to predict and prepare for incoming space weather, scientists and forecasters make predictions of the Sun's conditions twice daily. But solar imagers are sending back a new set of data every few minutes so machine learning can highlight the anomalies that could have a huge impact on space weather.



The past, present and future of solar exploration

Sending missions to the Sun isn't the same as sending a mission to another planet. The Sun's radiation makes it near impossible to get up close and personal. There have been many satellites launched with the purpose of observing and understanding the Sun's activity, the first dating back to 1960 with NASA's Pioneer 5 spacecraft.

Since then, instruments, engineering processes and our understanding of the solar environment have drastically improved. This has led to a better investigation of the Sun. A few missions that have been incredibly influential in our understanding include NASA and the European Space Agency's (ESA) Solar and Heliospheric Observatory (SOHO), NASA's Solar Dynamics Observatory (SDO) and the Japan Aerospace Exploration Agency (JAXA) mission - with collaboration from NASA and the United Kingdom - called Hinode.

On 12 August 2018, NASA launched its Parker Solar Probe. With some of its results already having been mentioned, it is obvious how this mission is breaking boundaries when it comes to scrutinising the Sun. At its closest approach the PSP will travel within the Sun's atmosphere at a distance of 3.8 million miles from the surface. This is why it is often said that this mission will 'touch the Sun'. This mission carries with it four specially designed instrumental suites that look to answer questions about the corona and solar wind while experiencing temperatures of roughly 1,377 degrees Celsius (2,500 degrees Fahrenheit).

In 2020, the ESA will launch its Solar Orbiter, another revolutionary solar mission in its own right. This mission will get close to the Sun - but not as close as the PSP - at a distance of 41.8 million kilometres (26 million miles) from the surface. The main difference is that the Solar Orbiter will utilise the gravity of Venus to swing it into a greater inclination, potentially as high as 33 degrees. This will allow it to probe the poles of the Sun, a feat that has never been accomplished by any other spacecraft before.

Below: Intense solar activity could have damaging effects for the Earth, so satellites are constantly watching it



Honourable mentions for solar explorers

- **Mission:** Helios
Operator: NASA/German Aerospace Center (DLR)
Active years: 1974 to 1986
- **Mission:** Ulysses
Operator: NASA/ESA
Active years: 1990 to 2009
- **Mission:** Solar and Heliospheric Observatory (SOHO)
Operator: NASA/ESA
Active years: 1995 to present
- **Mission:** Genesis
Operator: NASA
Active years: 2001 to 2004
- **Mission:** Deep Space Climate Observatory (DSCOVR)
Operator: NASA/National Oceanic and Atmospheric Administration (NOAA)
Active years: 2015 to present
- **Mission:** Parker Solar Probe
Operator: NASA
Active years: 2018 to present
- **Mission:** Solar Orbiter
Operator: ESA
Active years: 2020 to present

Sun facts

1.3 million Earths could sit within the Sun, and around 1,000 Jupiters could fit into the Sun.

At the equator of the Sun, it takes 25 days to complete one full rotation, but regions towards the poles take closer to 36 days.

The Sun contains traces of heavier elements such as oxygen, carbon, neon and iron.

Sunspots are darker, cooler spots that appear on the Sun's photosphere that arise from complications within the star's magnetic field.

The shape of the Sun relies upon hydrostatic equilibrium, which means the pressure of gravity is equal to radiation output.

The Sun is classified as a main sequence star, and based on its spectral classification is also known as a G2V-type.

An Astronomical Unit (AU) is the distance between the Sun and Earth and is used to describe distances in the Solar System.

SPACE'S *Stunning* NEBULAE

From when they burst into life through to their often explosive end, stars form beautiful, vibrant and mysterious imprints in the universe. Here are the most spectacular

Written by Baljeet Panesar

BUBBLE NEBULA

► Hubble's snap of a majestic, giant cosmic soap bubble was selected to mark Hubble's 26th year in space. This seven-light-year-wide bubble, also known as NGC 7635, can be found some 8,000 light years away in the constellation Cassiopeia.

Within the bubble sits the massive, super-hot star SAO 20575, which is 45-times more massive than the Sun. Gas from the star - its stellar wind - escapes at speeds of over 6.4 million kilometres (4 million miles) per hour, providing the pressure to force the interstellar material outward, forming the bubble shape. The star is 4 million years old, and will explode in a spectacular supernova in roughly 10 to 20 million years.

CAT'S EYE NEBULA

▼ One of the most complex planetary nebulae, NGC 6543 was first observed by William Herschel in 1786 and calls the Draco constellation home, lying 3,000 light years away. 11 or more concentric gas shells, high-speed gas jets and gas knots can all be found within this intricate and amazing shape. When the star blasts out material it forms these rings, which happens around every 1,500 years. Each pulse of material contains as much mass as all the planets in our Solar System, and since first being observed it has continued to expand.



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LOBSTER NEBULA

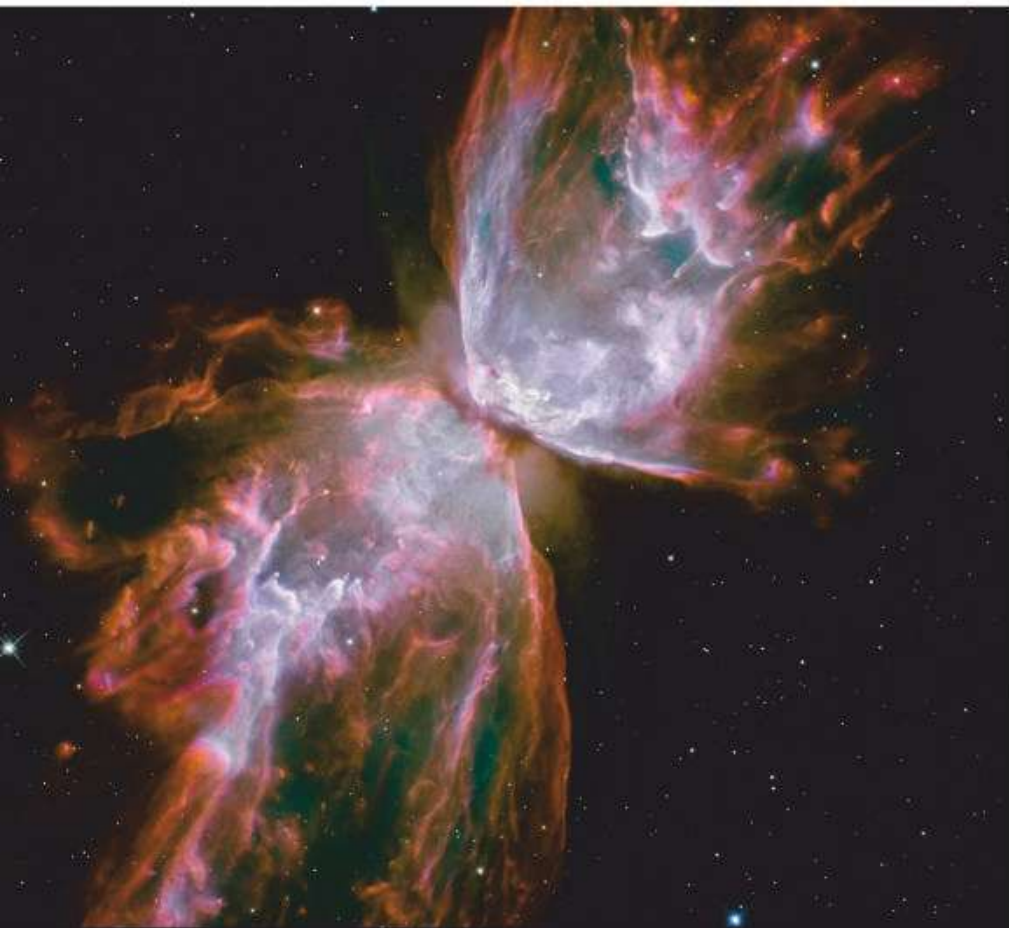
▲ In a cosmic 'winter wonderland' 5,500 light years away in the constellation of Scorpius lies a region called NGC 6357. Here, many hot, young stars are born in the tumultuous clouds of dust and gas, energising the surrounding gas. Aged only a few million years old, these are young stars by cosmic standards, and their icy blue hues, together with the oranges and whites, create an idyllic wintry landscape.

CARINA NEBULA

► 7,500 light years away lies the southern constellation of Carina (the Keel), home to the Carina Nebula, or NGC 3372. This giant nebula is home to at least a dozen massive stars that range between 50 and 100 solar masses, the oldest of which are about 3 million years old.

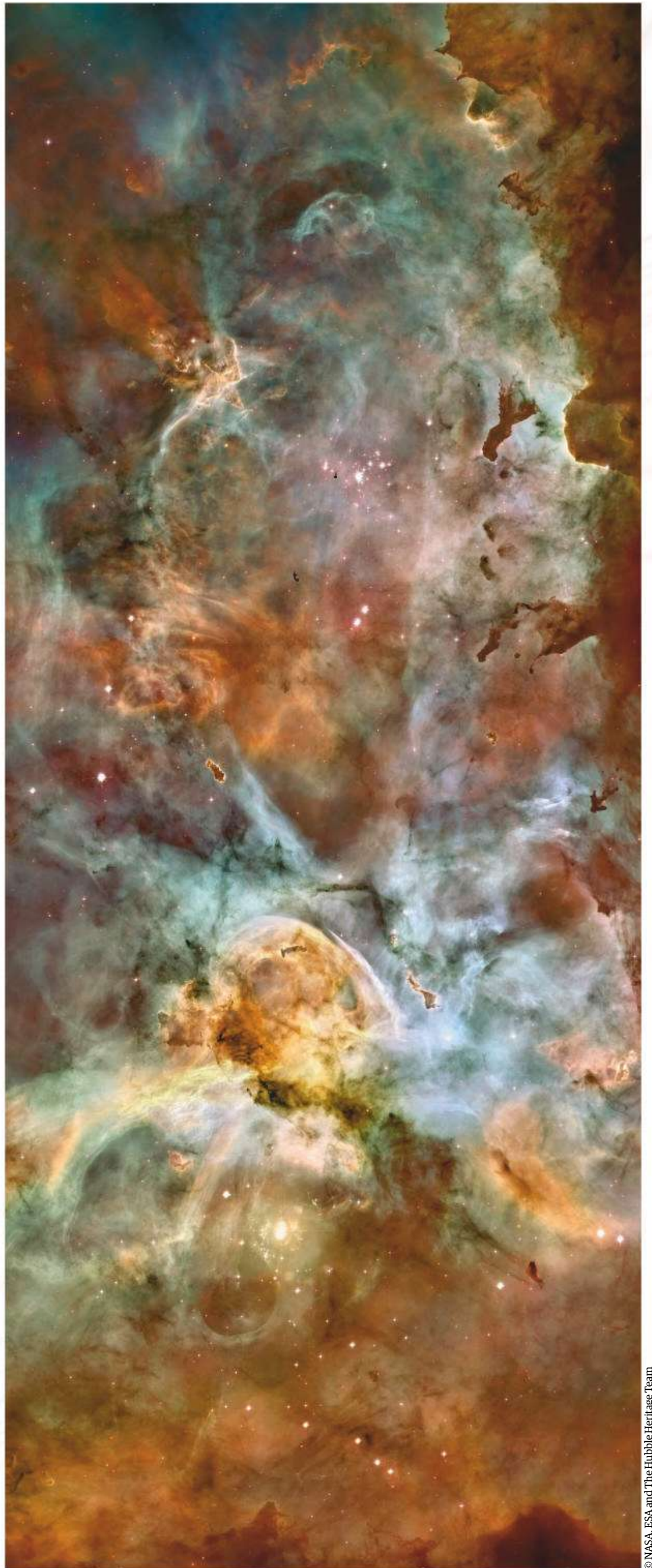
One of its most famous residents is the binary star system Eta Carinae. The larger of these stars is 90 times the mass of the Sun, while a smaller star that weighs 30 times the Sun's mass circles this massive behemoth. The more massive star is destined to explode in a cataclysmic supernova explosion, and blasts out material at speeds of 1.6 million kilometres (1 million miles) per hour.

"This giant nebula is home to at least a dozen massive stars that range between 50 and 100 solar masses"



BUTTERFLY NEBULA

▲ Lying 4,000 light years away in the constellation of Scorpius, its wingspan reaches three light years across. The butterfly's wings are made from gas which reaches temperatures of nearly 20,000 degrees Celsius (36,032 degrees Fahrenheit) and moves at speeds of 950,000 kilometres (590,300 miles) per hour through the cosmos. This glowing gas has been expelled for about 2,200 years. Even the dying star at its centre reaches surface temperatures of over 220,000 Celsius (396,032 degrees Fahrenheit), making it one of the hottest known stars in the Milky Way. It was once five times the mass of our Sun, but it's now hidden within a dusty torus, which creates the characteristic hourglass shape of planetary nebulae.





TARANTULA NEBULA

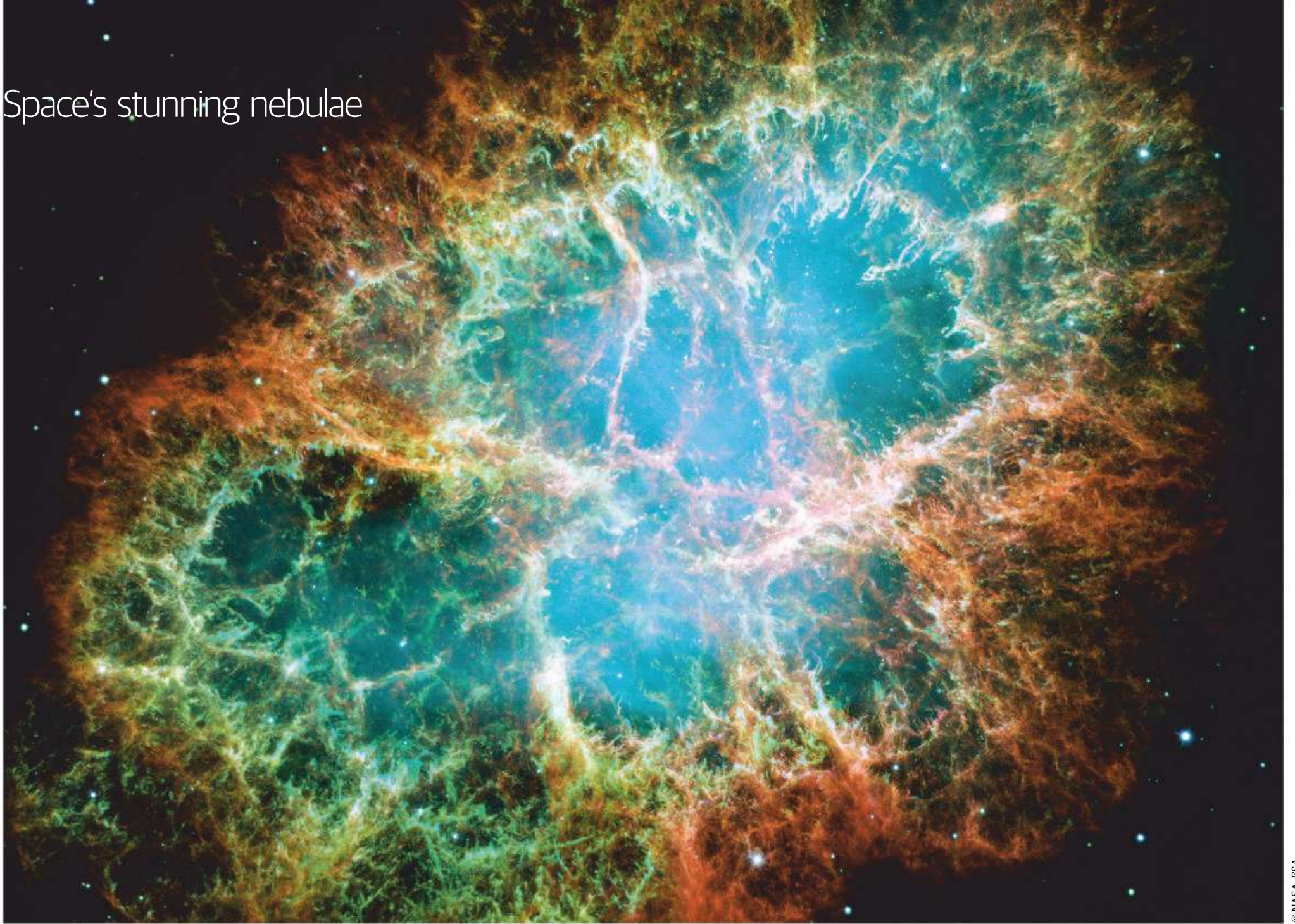
▲ This spindly space arachnid is one of the largest and most intense regions of active star formation in our galactic neighbourhood. Glowing 170,000 light years away, it's one of the most spectacular features of the Large Magellanic Cloud, a small satellite galaxy of the Milky Way. At roughly 1,000 light years wide, the nebula can be found in the Dorado constellation. It reveals a cosmic landscape of star clusters, glowing gas clouds and the scattered remains of supernovae explosions. This spectacular image reveals star clusters that are aged between 2 million and 25 million years old, iridescent gas clouds and the remnants of supernovae explosions.

LAGOON NEBULA

► To celebrate Hubble's 28th anniversary, the telescope turned its attention to a star-forming region known as the Lagoon Nebula, or Messier 8, some 4,100 light years away. The mountain-like clouds of dust, ridges and cavities are carved by violent stellar winds and ultraviolet radiation from a young star at its heart.

This giant star is called Herschel 36, and it's 32-times more massive than the Sun. At only 1 million years old, this is a young star that will live for another 5 million years or so. Within these clouds, stars are born as well as destroyed. Elephant-like trunks like those seen in the Pillars of Creation protect newborn stars while the release of material from the young sun prevents the formation of stars around it.





© NASA, ESA

CRAB NEBULA

▲ Assumed to be the gaseous remnant of an exploding star, it was first observed by Chinese astronomers in 1054. This 'guest star' was visible in the daytime sky for 23 days, and for nearly two years in the night sky.

Sitting in the constellation of Taurus, 6,500 light years from Earth, the Crab Nebula spans 11 light years and continues to grow at a speed of 1,100 kilometres (700 miles) per second. At the centre of the nebula is a rapidly spinning neutron star - a pulsar - that's 30 kilometres (19 miles) wide, ejecting pulses of radiation from gamma rays to radio waves - one of the few cosmic objects to do so. This gives the centre its eerie, blue glow. Charles Messier mistook the nebula for Halley's Comet, and it was discovered in 1731 by John Bevis.



ENGRAVED HOURGLASS NEBULA

◀ A young planetary nebula also known as MyCn18, it lies some 8,000 light years away in the constellation of Musca. Although it had been discovered nearly 100 years before, the hourglass structure was only first observed in 1996.

Two large outer rings and a smaller central ring form the nebula, with a bright 'eye' in the centre of the image. This shape was formed by the rapid expansion of the stellar wind within the cloud, which is denser at the equator than the poles.

At the heart of the nebula lies a Wolf-Rayet star, a hot, massive star that is unexpectedly off-centre. One possible explanation could be that there is a companion star in a binary system. Other unusual features that Hubble revealed were the intricate patterns of 'etchings' in its walls and two intersecting rings in the centre. The red in the image represents nitrogen, green is hydrogen and blue is oxygen.

© NASA, JPL

EAGLE NEBULA'S PILLARS OF CREATION

◀ Back in 1995, Hubble snapped one of its most iconic images in history, dubbed the 'Pillars of Creation'. Almost 20 years later, Hubble revisited these famous pillars with its higher resolution Wide Field Camera 3.

These three five-light-year-tall towers of cosmic gas and dust are birthing new stars deep within their wispy pillars. Violent winds and intense ultraviolet radiation from a cluster of young, massive stars are slowly destroying the pillars. The towers can be found within the Eagle Nebula, or Messier 16, roughly 6,500 light years from Earth in the Serpens constellation. The colours represent different chemical elements. The blue represents oxygen, red is sulphur and green is nitrogen and hydrogen.

MEET BRUIE

THE UNDERWATER EXPLORER

This rover could one day be searching for signs of life on icy water worlds

There has been an undeniable emphasis on exploring worlds in our Solar System with subsurface oceans, and Jupiter's moon Europa and Saturn's moon Enceladus are both prime targets. These two celestial bodies have drawn a lot of attention because they have both shown promising signs of hosting a liquid-water ocean. This draws comparisons with Earth's huge amount of water and its importance for life. This makes a lot of people believe there is life hiding underneath their frozen lunar crusts.

Engineers are now devising creative ideas that could allow robotic submersibles to explore the environments underneath these slabs of ice - which can be as thick as ten to 19 kilometres (six to 12 miles) - for months at a time. One unique idea that has been proposed by engineers at NASA's Jet Propulsion Laboratory (JPL), situated in Pasadena, California, is a buoyant robotic explorer that will essentially walk on the ceiling of an ice sheet. The Buoyant Rover for Under-Ice Exploration, or 'BRUIE' for short, would take a suite of scientific instruments that will examine the aquatic environments of these alien oceans while trying to find signs of life.

The BRUIE team has even put together a prototype that's been tested in Alaska and the Arctic. At the time of writing, it had started testing in Antarctica. The BRUIE prototype is a one-metre (three-feet) long buoyant

rover equipped with two wheels, cameras and a scientific instrumental suite capable of measuring the water's dissolved oxygen, water salinity, pressure and temperature.

"The ice shells covering these distant oceans serve as a window into the oceans below, and the chemistry of the ice could help feed life within those oceans. Here on Earth, the ice covering our polar oceans serves a similar role, and our team is particularly interested in what is happening where the water meets the ice," said Kevin Hand, JPL lead scientist on the BRUIE project.

Australia's Casey research station in Antarctica provides one of the best analogues of icy water worlds on Earth. The rover was placed on a



Ice-water interface

Testing of the prototype focuses on how the explorer operates in the ice-water interface and makes sure it maintains buoyancy.

Search for life

This aquatic explorer will be fitted with instruments and high-definition cameras that will search for alien life or understand if these off-world oceans have hospitable conditions.

Deep diving

The robotic explorer may need to survive for months underneath an ice sheet between ten and 19 kilometres (six and 12 miles) thick.

Potential visits

Some of the worlds in the Solar System that have shown signs of a subsurface ocean are Jupiter's moons Europa, Ganymede and Callisto, as well as Saturn's icy moon Enceladus.

tether and navigated around the region where water meets ice, also referred to as the 'ice-water interface'. This area has been known to cause problems for other submersibles, as the ocean currents cause robotic explorers to either crash or waste a lot of energy on maintaining their position. However, BRUIE will use buoyancy to its advantage, acting as a sort of reverse-anchor on the ceiling of the ice. From this position, BRUIE will be able to collect images and data of the surrounding area.

The scientific instruments will measure several aspects of Antarctica's water, but scientists still have no definitive idea what chemistry resides within the alien oceans. It may be that in order to detect alien life within these worlds, scientists will need a completely different set of instruments. This is why upcoming missions such as NASA's Europa Clipper are important, as they will provide a clearer understanding of the true chemistry of an icy moon such as Europa. This will in turn provide astronomers and engineers with a better idea of what instruments BRUIE will need in order to scrutinise the subsurface ocean.

Buoyancy is key

BRUIE will have an air-sealed cylindrical body that will provide the all-important buoyancy.

Hoag's Object



THE IMPOSSIBLE GALAXY

Hoag's Object is strange enough as it is, but astronomers can also see a galaxy within the galaxy within a galaxy

Reported by David Crookes

The universe is a gorgeous place, but some images have a greater power to stop you in your tracks than others. "Hoag's Object is fascinating because of its aesthetic value; it's just a beautiful thing," Dr Noah Brosch tells *All About Space* about one particular intergalactic gem. Indeed, one glimpse at its perfect circular ring of blue stars around a golden central ball and there's no denying that most people would find it hard to tear their eyes away.

The ring-shaped galaxy was discovered by American astronomer Arthur Hoag in 1950. He had been working at the US Naval Observatory and originally thought the object was an ejection of ionised gas from a red giant star in its last throes of life - a planetary nebula.

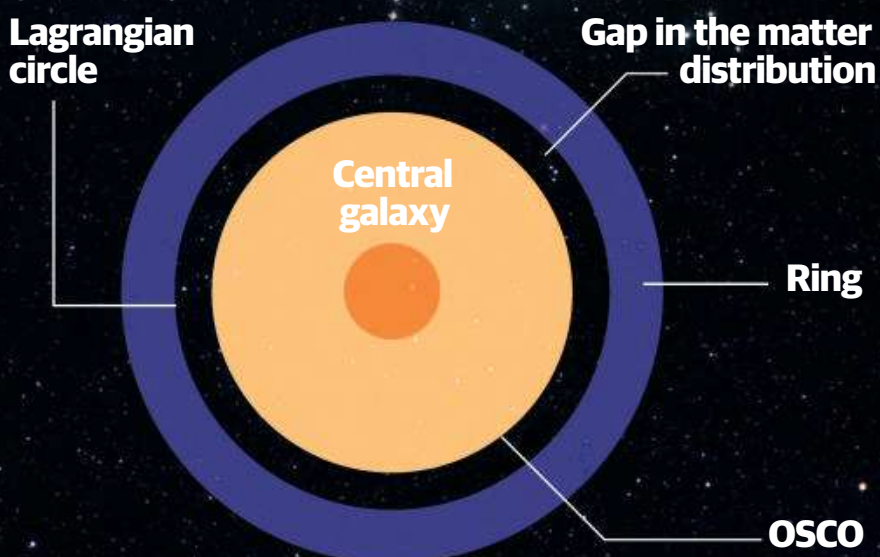
Rejecting his own hunch on the grounds that the ring's light was not being emitted at the expected wavelengths, he later theorised that the whole thing may have simply been an Einstein ring - an optical illusion caused by gravitational lensing of the source's light. After all, in the very early images of the galaxy, a blue ring was seen to encircle a yellow core, and the Einstein ring was a suitable explanation. As clearer images of Hoag's Object came into view in the late 1980s, however, that idea was soon dismissed too.

What remains is a mystery that astronomers are keen to figure out. The pictorial evidence is of a galaxy within a galaxy - two stellar circles separated by a dark gap - but studies have shown that they are both at the same distance from Earth since they have an identical redshift. This

points to them being one galaxy rather than two. In actual fact, it's a peculiar galaxy quite unlike the majority of others. It is an immense eye-catching structure of gigantic proportion.

In terms of specifics, the red, dead inner core is 17,000 light years across. The dark ring around it measures 50,000 light years and the overall object from one side to the other is 120,000 light years, making it slightly larger than the Milky Way. The outer bright ring of stars is 70,000 light years away from the central component. What is perhaps most stunning, though, is that if you look even closer you can see another ring-shaped galaxy in the gap, pointing to a galaxy within the galaxy within a galaxy. It is simply jaw-dropping.

This has certainly been the takeaway of an image that has been doing the rounds of late. Taken by the Hubble Space Telescope and processed by geophysicist Benoit Blanco, the billions of blue stars are clearly separated from



HOAG'S OBJECT BY THE NUMBERS

1950

The year it was discovered
by Arthur Hoag

8 billion

Number of stars contained in
the galaxy

600 MILLION

Number of light years away
from Earth

120,000

Overall light-year distance of
the entire galaxy

70,000

Light years between the ring
and the central part

1

Another ring galaxy visible
within the gap

16.2

Apparent magnitude

3 billion

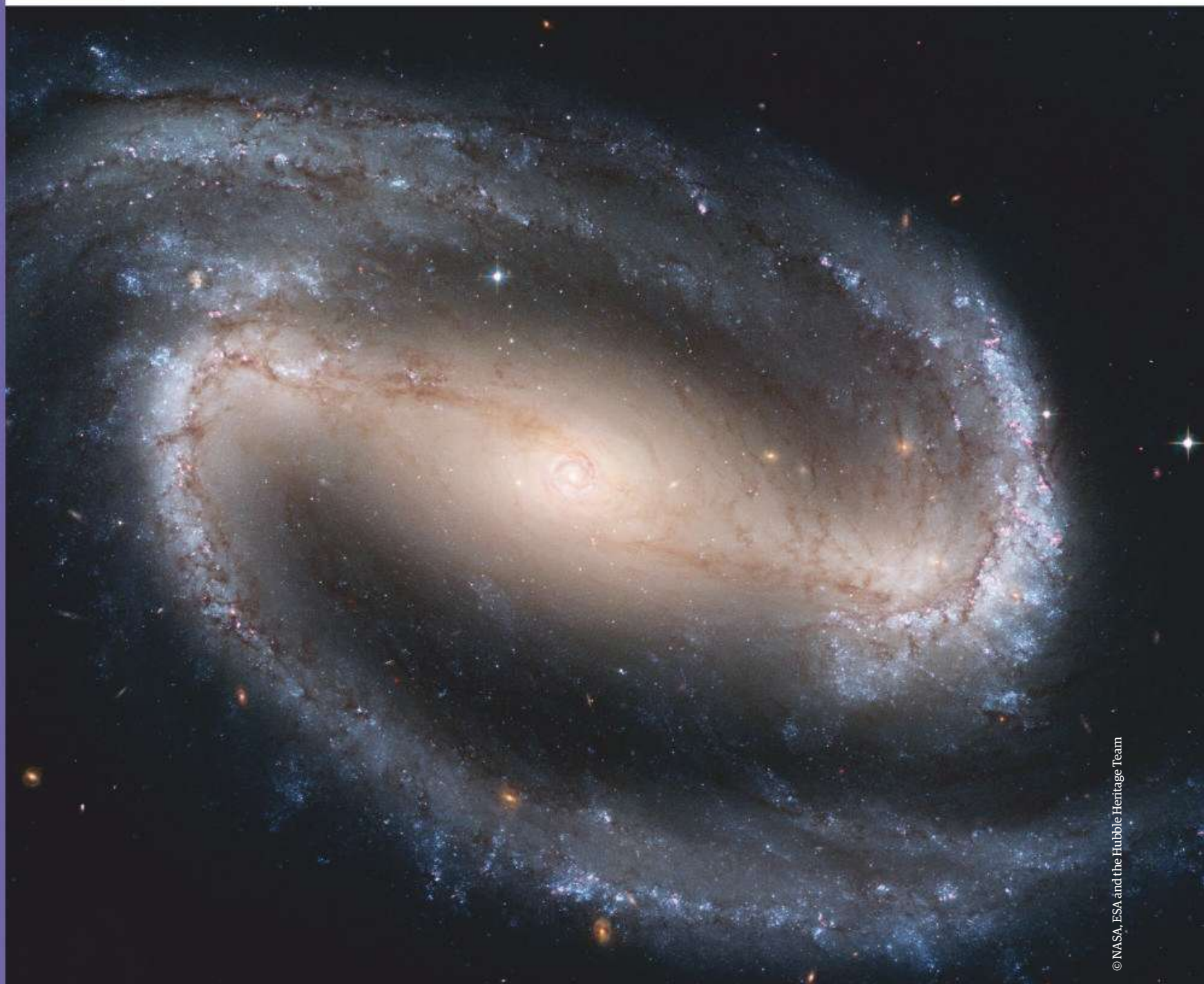
Years in the past that a
collision between two
galaxies may have happened

0.1

Percentage of all known
galaxies being ring galaxies

24,000

Light-year distance of the
inner core



Above:
According to
Noah Brosch,
extreme bar
instability in
a galactic disc
such as this
one could have
formed Hoag's
Object

the dense inner sphere made up of reddish stars. The other ring galaxy is visible as a red circle within the empty space - it's actually far away and not part of Hoag's Object itself. But the fact that it lines up in such a way that telescopes can pick up on it is nevertheless startling and a real cosmic coincidence.

"I think it's incredible that there's a ring galaxy in the background of a ring galaxy and that's why I choose this object for an advanced processing project," Blanco tells us, having made use of an artificially intelligent denoising algorithm. "I think it illustrates how infinite our universe is - the fact that in this case, you can look at a very unusual object and find one at the back." But how are these peculiar galaxies forming?

First things first. Hoag's Object - which is 600 million light years away from Earth towards the constellation of Serpens - is not a one-off, or even a two-off, given that we can see another peeking from the back. "Tens or more ring galaxies are known, but because of inclination and distance, none are as impressive as Hoag's," explains Brosch, who works at the department of astronomy and astrophysics and the Wise Observatory at Tel Aviv University in Israel.

Even so, that only accounts for about 0.1 per cent of all known galaxies, and it doesn't make such

peculiar galaxies, which also include NGC 1291 and PGC 1000714, easier to fathom. There have even been suggestions that an intelligent species is behind the phenomena, but those are perhaps the easiest to discard. "I think that explanation is all wrong," Blanco says. "When a very unusual event is observed in the universe, we think about aliens, but it's just that the universe is infinite and everything that can happen does seem to happen."

So what could account for the processes involved in Hoag's Object's formation? "The most probable explanation is that a spiral galaxy has been captured by a spherical galaxy, but it's unique for such a collision to create a perfect ring," Blanco says of an event which would have affected its gravitational pull. Such a thing is believed to have happened to other ring galaxies, resulting in new elliptical shapes, mergers or density waves. "It's likely to have happened because of a random collision 3 billion years ago that was so perfectly done, a part of the spiral material fell into the spherical and the remaining spiral created a perfect ring," he continues. Yet no one can say for certain.

Indeed, in 1985 Brosch suggested that Hoag's Object was a result of instability in a barred spiral galaxy billions of years ago. He theorised that the bar would have rotated, forcing gas to be pushed to

the outskirts where a ring would not only form, but stars and planets would end up being created.

Brosch also hypothesised that any old and dead stars would sink into the nucleus as the bar became used up and frittered away. But other scientists argued that it didn't account for why that central part of the galaxy is spheroidal rather than misshapen or elongated. With no evidence that the galaxy was barred to begin with, competing theories were worked upon.

In 1987 François Schweizer, W. Kent Ford Junior, Robert Jedrzejewski and Riccardo Giovanelli suggested Hoag's Object had formed from a merger with a smaller, lightweight galaxy. The gravity of the heavier, elliptical galaxy tore the visitor in such a way that the gas settled into orbit. With the heavier galaxy forming the core, the gas lends sufficient fuel for the formation of stars that eventually produced a separate ring. In this sense it would be on the same lines as a polar-ring galaxy, which are thought to occur when a couple of galaxies gravitationally interact with one another, producing an outer rotating ring of gas and stars.

One problem is that there is so much gas and stellar mass in that ring that it would have to have come from a galaxy far greater than a dwarf, in which case the disruption to the original galaxy would have been so great that Hoag's Object could not have formed in the way it has. There is also an issue of there being no sign of a second galaxy that could have collided, even with the use of the most sensitive of telescopes. To that end, Brosch revisited Hoag's Object in 2011 with Ido Finkelman,

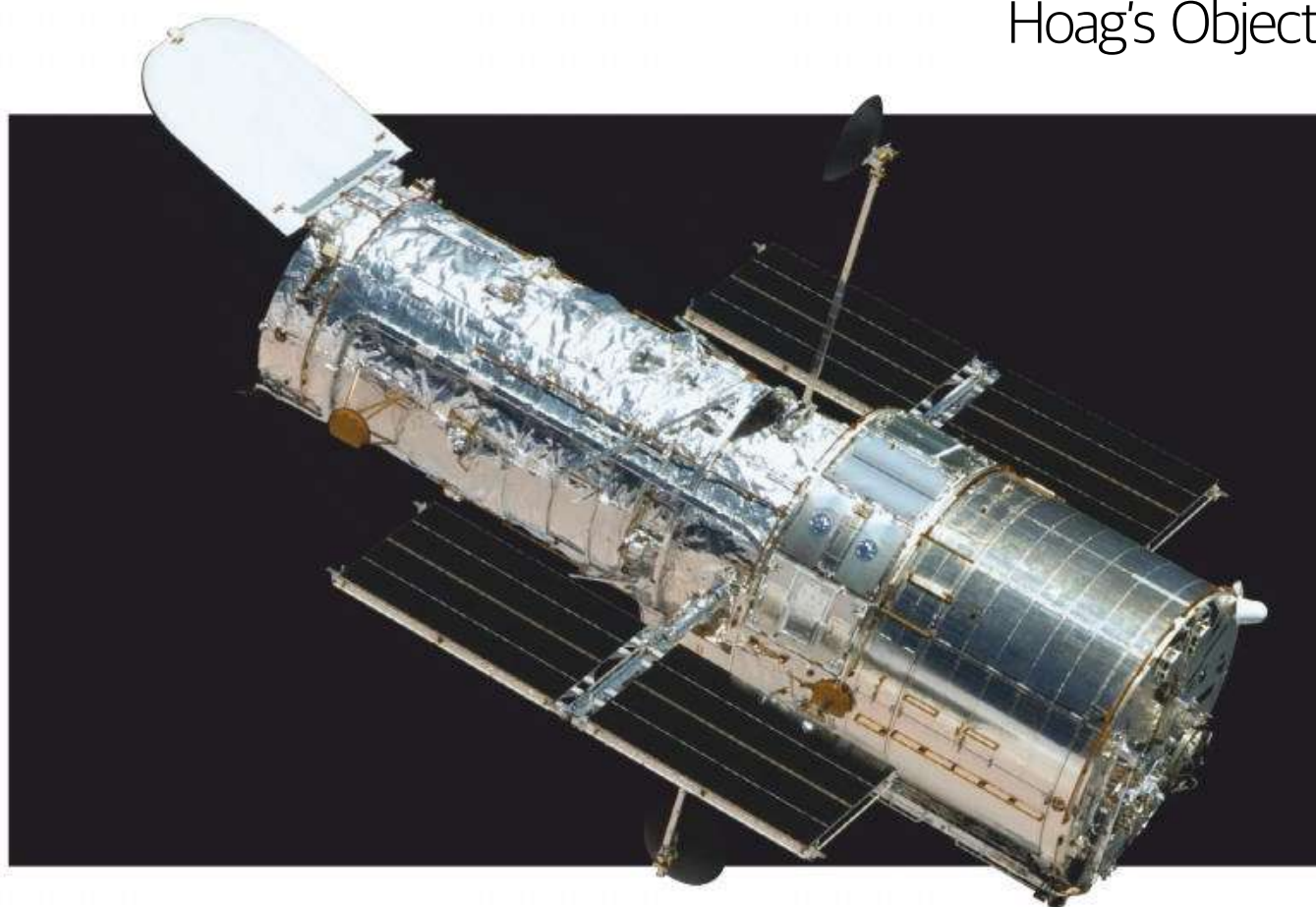
Alexei Moiseev and Ivan Katkov. Their paper said the elliptical core formed in the early universe, with the surrounding disc being created afterwards by "prolonged 'cold' accretion of primordial gas from the intergalactic medium".

In many ways their study was a continuation of Schweizer's theory. Kinematic data suggested Hoag's Object is a normal disc galaxy with a low-density hydrogen iodide disc that accretes onto the spheroid, and because of its lack of density forms stars in the ring. It's a theory that supposes gas floating in space is pulled in via gravity.

"My personal opinion is that the central elliptical-like object is old," Brosch affirms. "The star-forming

Above: The Hubble Space Telescope has been giving us a very close look at Hoag's Object

Right: American astronomer Arthur Hoag discovered the unusual ring galaxy in 1950 that became known as Hoag's Object



© NASA



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"I think it's incredible that there's a ring galaxy in the background of a ring galaxy; that's why I chose this object" **Benoit Blanco**

HOW HOAG'S OBJECT COULD HAVE FORMED

The possible steps taken towards creating an odd ring-shaped galaxy



1 A lightweight galaxy approaches a larger one

According to a study headed by François Schweizer in 1987, a lightweight galaxy may have come into close enough proximity to a heavier, elliptical galaxy for a major accretion event to have taken place.



2 Mass is transferred to Hoag's Object

At some stage - likely some 2 to 3 billion years ago - there would have been some level of interaction between the two galaxies which, short of a merger or collision, caused the mass to transfer to Hoag's Object.



3 Forming a surrounding ring

As the gravity of the heavier galaxy ripped the lighter one apart, transferred gas from the lightweight galaxy settled into orbit and fuelled the mass formation of stars, which over time formed a distinctive ring.



4 Evidence dissipates over the years

Any leftover detritus was then blown away into the universe over many years, which accounts for why there is no firm observational evidence of the event. Such scientific theory continues to be debated, however.

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THE THEORIES

What could account for the Saturn-like ring around this peculiar galaxy?

Collision between two nearby galaxies

Most ring-shaped galaxies are caused by a small galaxy colliding with a larger disc-shaped one, and while there is no evidence of a smaller galaxy having existed in the proximity of Hoag's Object, a collision remains a possibility. It would have torn a hole through a regular disc-type spiral galaxy and altered its gravitational pull.

Instability in a barred spiral galaxy

Brosch's hypothesis in 1985 suggested the ring formed in a similar manner to rings in barred spiral galaxies – that is, without any interaction and through slow internal evolution. With angular momentum transferred by the bar to the outer disc, gas is driven from the centre, creating the star-forming ring.

A close encounter of two galaxies

Rather than colliding, there could simply have been a close encounter of two galaxies which resulted in the pulling in of gas from one to the other via gravity. Some suggest that the surrounding ring could also have been caused by prolonged accretion of primordial gas which eventually led to the formation of material.

An alien-made structure

Joseph Voros of Swinburne University of Technology studied the possible "evolution of long-lived intelligent engineering species" which may have removed or lifted star systems and stellar material from galaxies, leaving a ring. He poses: "Is Hoag's Object an example of galaxy-scale macro-engineering?"

Top: This is the unbarred lenticular galaxy that can be seen shining from behind Hoag's Object

Above (right): An image created of Hoag's Object by Mike Herbaut using the free software program ESA/ESO/NASA FITS Liberator

Above (left): Hoag's Object was clearly visible on the Palomar Star Survey, but was missed off of a galaxy catalogues

ring is relatively young, and was formed by recent accretion of gas-rich material.

"This happened either by the tidal disruption of a dwarf galaxy followed by the ring formation, or by the direct accretion of gas and dust from intergalactic space with the inflowing material coming along a dark-matter filament that did not reach to the centre where the elliptical core is."

But what is stopping the outer ring from being pulled into the core? Why is this massive ring with ongoing star formation leaving a great gap between the two parts? To help answer this, in 2018 Elena Yu Bannikova from the Institute of Radio Astronomy of the National Academy of Sciences of Ukraine wrote a paper called 'The structure and stability of orbits in Hoag-like ring systems'.

In it she sought to explain where the forces between the core and the ring are gravitationally balanced. Through a series of mathematical equations she found that this was on the inner section of the ring – an unstable equilibrium called the Lagrangian circle. Furthermore, she found the outermost stable circular orbit (OSCO) is around the central galaxy.

"The masses of the central galaxy and the ring around it are comparable with each other," she tells **All About Space**. "The gravitational forces from the central galaxy and from the ring are acting in different directions, so there is a region where the gravitational field of the central galaxy is much stronger than from the ring, and the stars can move here in a circular orbit. There is also a region where the gravitational force from the ring is much more, so the stars will move around the ring.

"But there is also an intersecting region where particles and stars cannot move in a circular orbit due to competition between the gravitational forces from the central galaxy and the ring. We can say that the particles in this region do not belong in terms of gravitational attraction to either the central galaxy or the ring. It was surprising for me."

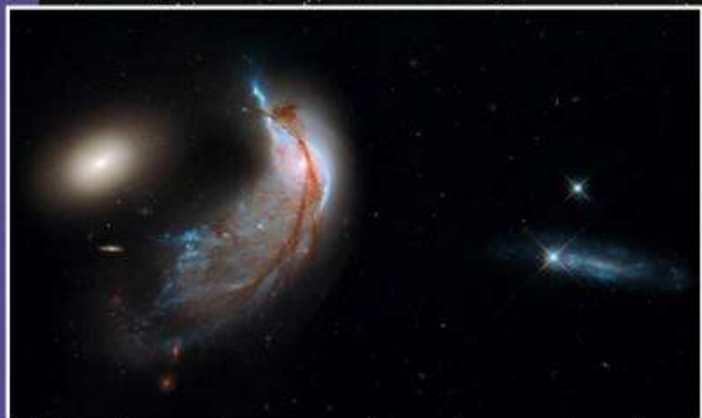
This accounts for why there is a gap in the matter distribution "where the circular motion is not possible due to the competition between the gravitational forces by the central mass and the ring" – that is, a great area where no stars or gas particles can orbit. It doesn't explain how it got to that state in the first place, but it points to why the ring remains and perhaps how the ring grew.

So what of that other ring-like galaxy that can be spotted far away behind Hoag's Object – the one catchily called SDSS J151713.93+213516.8 that has had a fair bit of recent media coverage since NASA made it its astronomy picture of the day on 27 November 2019? Unfortunately, although it can be clearly seen between the nucleus and the outer ring, it is too distant to get a proper close-up look, but the fact that it is there, in the same image as one so stark as Hoag, is simply delightful given their rarity. Both are likely to continue to fascinate astronomers for many years to come.

HOW ODD

There are many other weirdly formed galaxies out there

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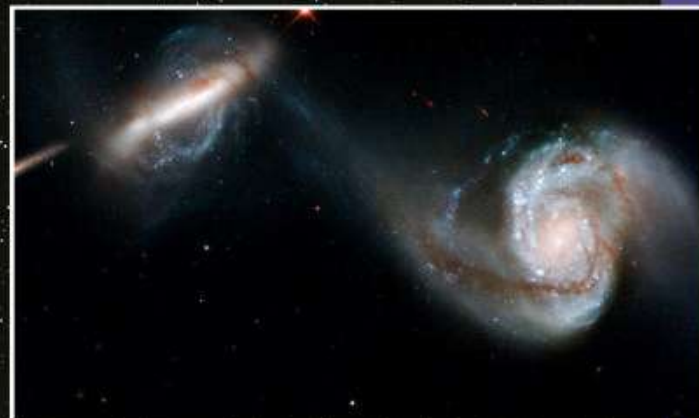
It looks like a penguin

NGC 2936 is 326 million light years away and it resembles a penguin, porpoise or dolphin depending on whose opinion you seek. It's actually a two-galaxy system, with an egg-shaped galaxy beneath called NGC 2937.

These galaxies are interacting

The peculiar spiral NGC 3808A and the irregular NGC 3808B are known collectively as Arp 87 and they're perhaps in a pre-merge state, having been very close to smashing into each other a few billion years ago.

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Tip your hat to this one

NGC 4594 is known as the Sombrero because it resembles a wide-brimmed hat with a bulge in the centre and a dark dust lane around it. Just 28 million light years from Earth, that bulge comprises several star clusters.

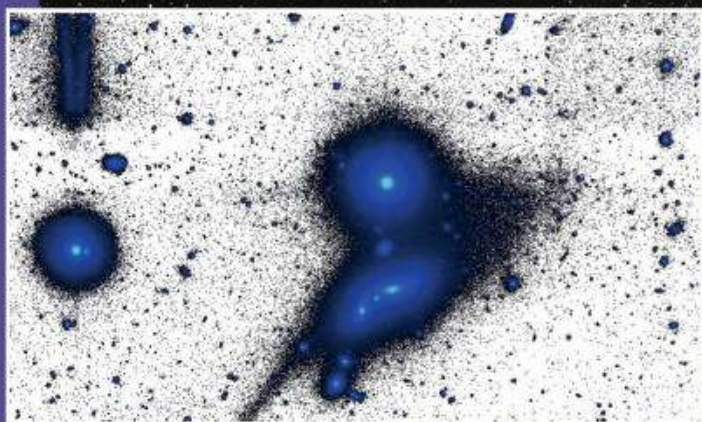
A supernova supersite

Messier 83 is a barred spiral galaxy in the constellation Hydra that's so bright it can be viewed using binoculars. Known as the Southern Pinwheel Galaxy, its swirls of pink and purple are punctuated by six observed supernovae.

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© RAS



A giant tadpole of a galaxy

This disrupted galaxy was identified by astronomers from Israel, the US and Russia. Created by a cosmic collision, the image shows an elliptical head and a long, straight tail that is 500,000 light years long.

The universe's most luminous galaxy

An extremely luminous infrared galaxy, W2246-0526 is 350 trillion times as bright as the Sun. In 2018 scientists observed it stripping close to half the mass of at least three of its smaller neighbours.

© NRAO/AUI/NSF



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A pair of eyes in the sky

Looking like an evil pair of eyes, NGC 2207 and IC 2163 are colliding spiral galaxies in the constellation Canis Major. The eyelids were formed by dust and stars following the interaction between the two galaxies.

A highly energetic galaxy

The elliptical galaxy NGC 474 in the constellation of Pisces shows multiple layers of emission that could be tidal tails related to debris that has been left over from the absorption of many small galaxies.

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Have a heart - or two

Spiral galaxy NGC 7674 has been seen to have a couple of radio jets with an S-shape. This could indicate the presence of a binary black hole. In this case, they would be a light year apart. The galaxy is likely a merger.

Galaxies devoid of dark matter

That's what astronomers saw in a wide-field imaging survey of the ultra-diffuse galaxy NGC 1052-DF2. Despite being as large as the Milky Way it has 200-times fewer stars, making it appear translucent.

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ASK Space

Our experts answer your questions

SPACE EXPLORATION

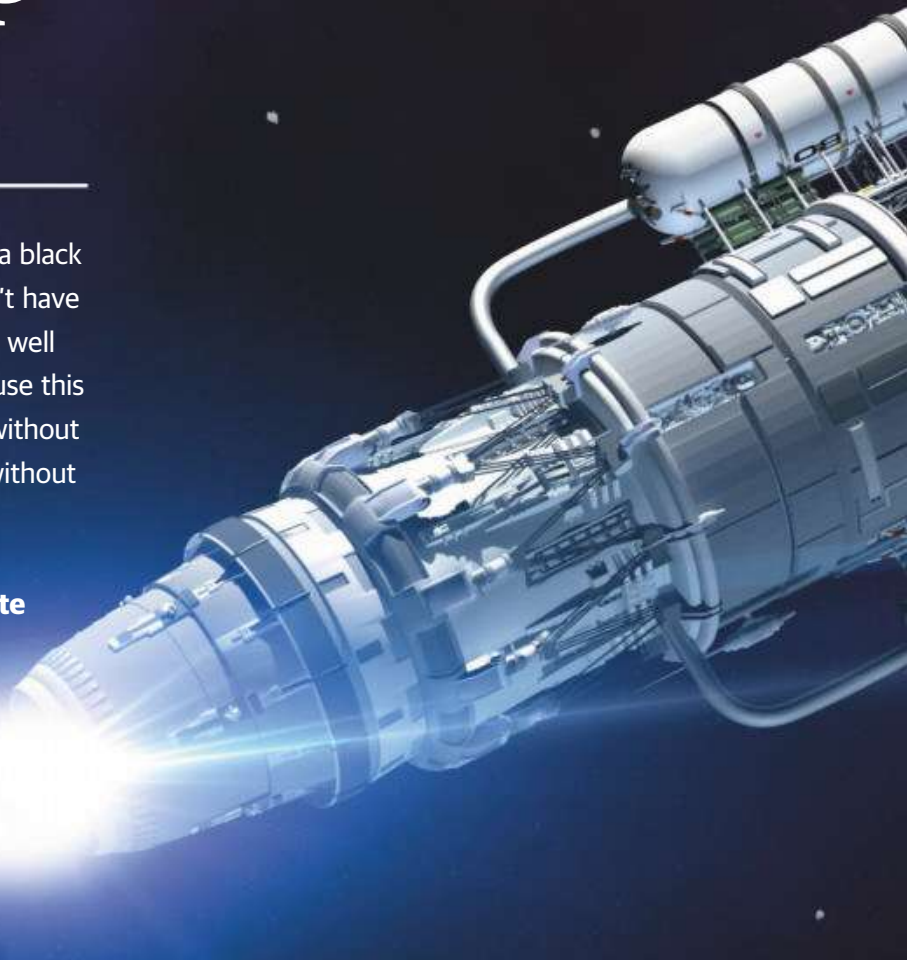
What are the chances of a spacecraft surviving a trip through a black hole?

Not much chance at all. But a trip to a black hole – that is, to the vicinity of a black hole – is not a problem. If you go to the event horizon you will go inside and very probably perish, but if you go near the black hole and if the black hole is big enough, the tidal forces don't kill you and don't destroy your ship. A slingshot around the black hole is a very powerful way to navigate through the universe.

If you have two black holes orbiting each other, you can bring a spaceship in and go on a slingshot around one of the black holes, then towards the other one and around, then back to the first one. If you design it so the black holes are moving towards each other, each time you launch from one to the other, you can accelerate up to very high speeds – a

large fraction of the speed of light if you have a black hole binary, particularly if it's elliptical. We don't have a black hole binary, so we can't do it, but I can well imagine that very, very advanced civilisations use this as a way of accelerating to very high speeds, without any discomfort for the intelligent beings and without using any fuel.

Kip Thorne was Feynman professor of theoretical physics at the California Institute of Technology until 2009 and a Nobel Prize laureate in physics in 2017



ASTROPHYSICS

What is the difference between pulsars and neutron stars?

A pulsar is a kind of neutron star: one that shows periodic pulsations. So all pulsars are neutron stars, but not every neutron star is a pulsar. Most neutron stars have strong magnetic fields, and as these stars rotate, this magnetic field rotates with them. That motion gives rise to a beam of radiation – like a flashlight – that points out from the magnetic poles. The rotation of the star then causes this beam to periodically sweep through our line of sight. Every time this happens, we see a brief pulse. Those pulses, which repeat at the exact rotation period of the neutron star, are what make it a pulsar.

How much radiation the star can produce this way depends on how fast it is spinning, and on how strong the magnetic field is. As the star ages, the pulses will disappear. It is still a neutron star, and we may still see it through other means, but it is no longer a pulsar. So what is the difference between a neutron star and a pulsar? Basically, just how we look at them.



Peter Bult is an astrophysicist at NASA's Goddard Space Flight Center, Maryland

Right: Pulsars and neutron stars are extremely powerful cosmic objects emitting large amounts of X-ray radiation

© NASA



Right: The idea of travelling through black holes has been used heavily in science-fiction

Below: Earth's tectonic activity was vital when it came to the evolution of life

"If you go to the event horizon you will go inside and very probably perish" **Kip Thorne**

Did you know?

Plate tectonics have shaped the continents throughout Earth's evolution, allowing humans to be widespread.

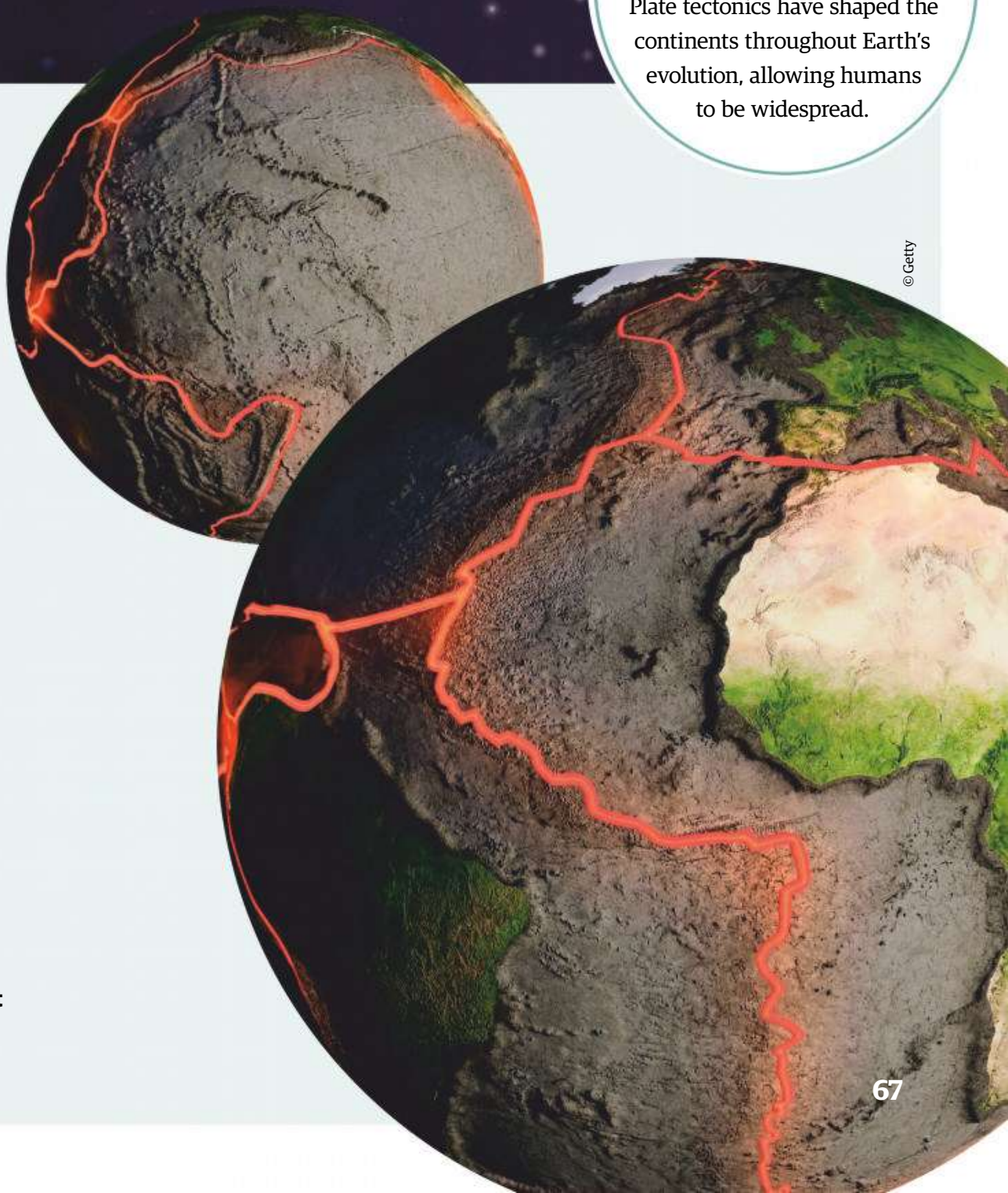
SOLAR SYSTEM

Are plate tectonics the biggest indicator for the evolution of life on another world?

There are other signs of life that you look for, like bacteria on Mars or bacterium in the oceans of Europa, but in terms of understanding how planets form and how they develop and change over their lifetimes, plate tectonics is one of those key fundamental forces. There seems to be evidence of a little bit of plate tectonics going on very early in Mars' history, which ground to a halt, and the planet started dying in a geological sense and it has very little volcanism today – it has kind of died inside.

But if we're looking beyond our Solar System, at extrasolar planets, the process of plate tectonics is a key feature to be looking for in a planet to be habitable and to host life. People talk about planets orbiting the habitable zone of their star – the planet is not too hot and not too cold for liquid water. We would be looking for planets with an appropriate atmosphere. Ideally it has a magnetic field to protect the atmosphere and any life from stellar winds and radiation and ideally things like plate tectonics. There's this understanding and explanation for how plate tectonics work on our own planet, what profound effects that's had on life, particularly in the origin of humans, and how that links to other planets in our Solar System and what we'd be looking for in exoplanets we would hope to find life on.

Lewis Dartnell is a professor of science communication at the University of Westminster



© Getty



ASTROPHYSICS

What happens in gravitational

Gravitational lensing occurs when light from a distant source passes through the gravitational field of another object. The gravity of the intervening object bends the path of the light rays, similar to how the base of a wine glass bends, distorts and magnifies light. In weak lensing, the light is only slightly bent, distorting the shape of background galaxies. In strong lensing, light from the background source is bent so much that it splits into multiple images. Strong lensing requires the background source and foreground lens to be nearly perfectly aligned along the line of sight.

Gravitational lensing is used to study both the lenses and the sources. Sometimes it is used to map out the distribution of matter – including dark matter – in the lens. Other times we can take advantage of the magnification effect to study source galaxies that would otherwise be too faint and too far away.

Microlensing is a term used when the lenses are individual stars. In microlensing, we measure the change in magnification as a function of time as a background source star and a foreground lens star move in and out of alignment.

Jennifer Yee is an astrophysicist at the Harvard & Smithsonian Center



for Astrophysics in Cambridge, Massachusetts

Right: Massimino had to train in the Neutral Buoyancy Lab in order to repair the Hubble Space Telescope in space

SPACE EXPLORATION

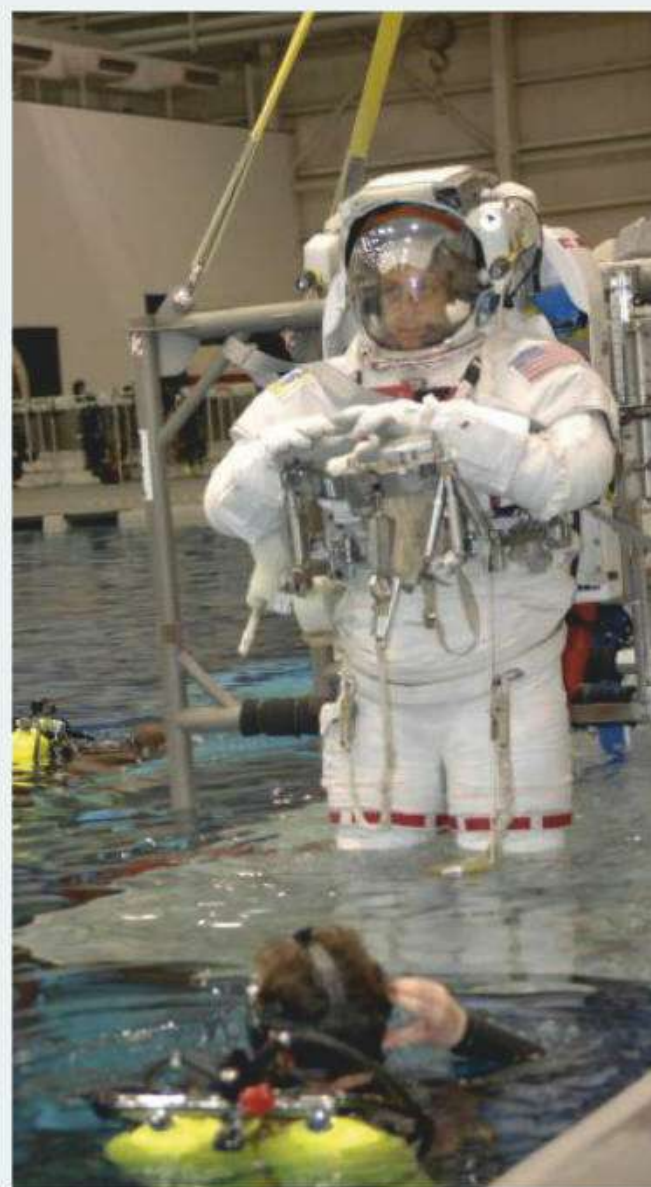
What's involved in training to go into space?

As an astronaut you get trained to do all kinds of things: learn to fly in a high-performance plane, learn the systems of the Space Shuttle and the Space Station and learn how to work as a team in simulations. My primary job on my missions was to operate the robotic arms. However, I ended up being the spacewalker. To do that, you piece together different experiences – including stuff in virtual reality – and we had lessons where we had to learn about the spacesuit and so on.

It all seemed to come together in our big pool – the Neutral Buoyancy Laboratory. It's the largest pool in the world and you can fit an entire Space Shuttle inside it. You can practice what you're going to do in space in the water. You're floating in the water column like you'd be floating in space. Many hours, days, weeks and months of my life add to my days at work in the Neutral Buoyancy Lab. It was a wonderful experience training for a spacewalk.



Mike Massimino is a retired NASA astronaut and veteran of two space missions, STS-109 and STS-125



© NASA

COSMOLOGY

Why did Population III stars lack planets?

Population III stars were the very first stars in the universe, back in a time when it consisted exclusively of hydrogen and helium. Any heavier elements would only form once massive stars died in violent supernova explosions, and therefore only be available to the following generations of stars. Yet planets, which form simultaneously with their star, rely on these heavy elements. In the predominant paradigm of planet formation, a solid core has to form from these components before any gaseous atmospheres can build up. So the basic building blocks to form planets were not available around these earliest stars.

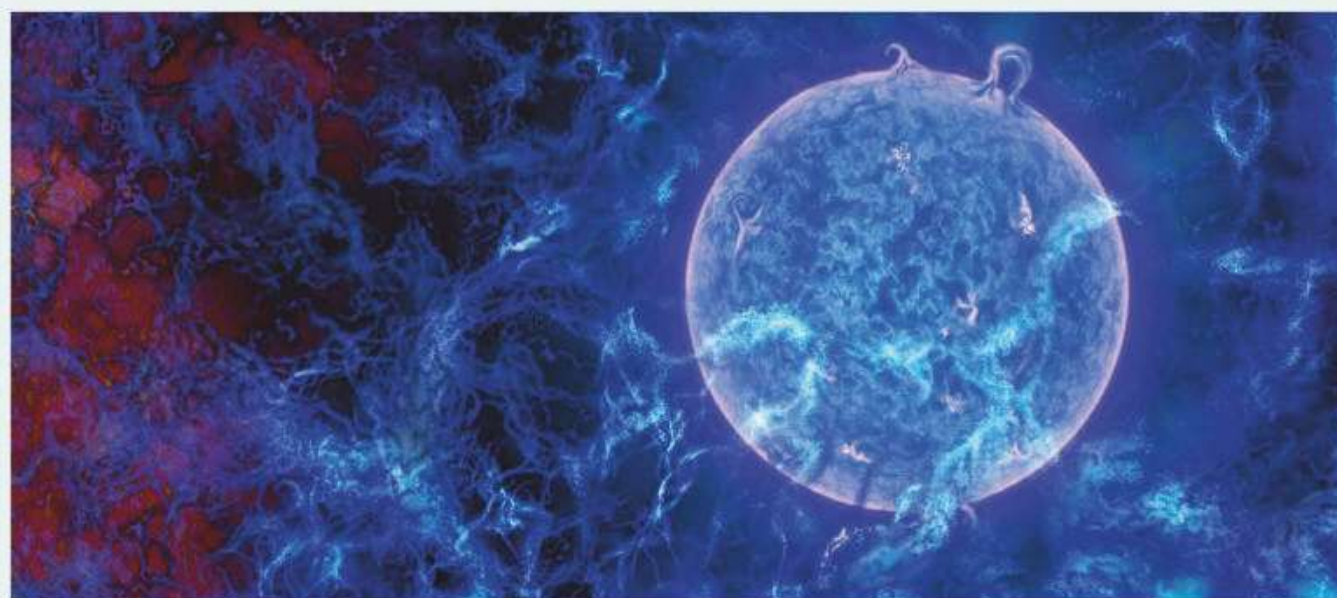
Even if some planets did form around these unusual stars, they would be far from habitable: with surface temperatures of about 100,000 Kelvin, their host stars emitted deadly ultraviolet radiation. At the end of their short lives, Population III stars exploded in devastating supernovae. While this was certainly not a very inviting neighbourhood to live in, these very explosions produced the heavy elements that today's planetary systems, including our own, are made of.



Dr. Jeremy Schnittman is a research astrophysicist at NASA's Goddard Space Flight Center, Maryland

Left: An Einstein cross is when a distant quasar has been lensed into four distinct images by a foreground galaxy

Right: The first stars likely formed 200 million years after the Big Bang



© N.R. Fuller, National Science Foundation

SOLAR SYSTEM

Is there any relation between comets and Kuiper belt objects?

Comets are relatives to, and in some cases direct descendants of Kuiper belt objects (KBOs). They are dark like comets, but larger than most – but not all – comets; for instance, Comet Hale-Bopp is larger.

These objects are motivating a lot of modelling work to see how to create 'primordial binaries' and how to make them survive for billions of years. KBOs are objects that are in distant orbits, either because they formed there, like in the cold classical belt, or were placed there due to early evolution of the large planets in the Solar System. The orbits of some of the objects become disrupted for some reason, and they get closer and become Centaurs – objects that cross the orbit of the outer giant planets. If they get further perturbed to the inner Solar System, they show up as what we classically call 'comets'.

Ultima Thule has been in the distant outer Solar System in cold storage for its entire life, so it likely has lots of ices not too far below the surface and throughout. If you moved it into the inner Solar System, the heat from the Sun would go deep into Ultima Thule, evaporating those ices, and they would escape as gas, dragging dust with the gas, which is exactly what a comet is.



Joel Parker is director of operations at the Southwest Research Institute, Boulder, Colorado, and was also part of the science team for NASA's New Horizons and ESA's Rosetta missions

Did you know?

Pluto's status as part of the Kuiper belt was part of the reason it was reclassified as a dwarf planet in 2006.

Right: Kuiper belt objects, such as Ultima Thule, are found beyond the orbit of Neptune

ARE WE WRONG ABOUT HUBBLE'S CONSTANT?

Disagreement on the speed of the universe's expansion continues according to recent research

Reported by Adam Mann

By looking at how the light from distant bright objects is bent, researchers have increased the discrepancy between different methods for calculating the expansion rate of the universe. "The measurements are consistent with indicating a crisis in cosmology," Geoff Chih-Fan Chen, a cosmologist at the University of California, Davis, said. At issue is a number known as the Hubble constant, first calculated by American astronomer Edwin Hubble nearly a century ago after he realised that every galaxy in the universe was zipping away from Earth at a rate proportional to that galaxy's distance from our planet.

This does not mean that Earth is at the centre of the cosmos. Instead the finding told scientists that the universe is expanding and that there is a direct relationship between how far apart two objects are and how fast they are receding from one another. The Hubble constant has a value that incorporates this speed-distance connection.

The problem is that in recent years, different teams have disagreed over what exactly this constant's value is. Measurements made using the cosmic microwave background (CMB), a remnant from the Big Bang that provides a snapshot of the infant universe, suggest that the Hubble constant is 74,350 kilometres (46,200 miles) per hour per million light years.

"At issue is a number known as the Hubble constant, first calculated by American astronomer Edwin Hubble"

But by looking at pulsating stars known as Cepheid variables, a different group of astronomers has calculated the Hubble constant to be 81,110 kilometres (50,400 miles) per hour per million light years. The discrepancy seems small, but there is no overlap between the independent values, and neither side has been willing to concede major mistakes in its methodology.

The new measurement, made by the H0 Lenses in COSmological MONitoring of GRAvitational Lenses' (COSMOGRAIL) Wellspring (HOLICOW) collaboration, was an attempt to calculate the Hubble constant in a completely novel way.

This measure uses the fact that massive objects in the universe will warp the fabric of space-time, meaning that light will bend as it travels past them. Superluminous black-hole-powered entities called quasars are sometimes found behind large foreground galaxies, and their light gets warped by this bending process, which is known as gravitational lensing.

Using the Hubble Space Telescope, the HOLICOW team studied the light from six quasars between 3 billion and 6.5 billion light years away from Earth. As the quasars' black holes gobbled

material, their light would flicker. The intervening gravitationally lensing galaxy bent each quasar's light, and so the quasar's flickering arrived at Earth at different times depending on what path it took around the foreground galaxy, Chen explained. The length of the time delay provided a way to probe the expansion rate of the universe, he added.

HOLICOW was able to derive a value of the Hubble constant of 81,000 kilometres (50,331 miles) per hour per million light years, extremely close to that provided by Cepheid variables but quite far from the CMB measurement.

"The consequence is the tension is very well likely real," Chen said, and probably not the result of errors in the methods of each approach. It's worth noting that last year another independent measurement of the Hubble constant, made using giant red stars, came squarely between the two sides, calculating a value of 76,122 kilometres (47,300 miles) per hour per million light years.

Nevertheless, Chen said, the different numbers are far enough apart that it's possible there is something wrong in our models of the universe. A growing number of physicists are acknowledging this, he added, because the independent measurements continue to disagree.

Above: The universe is rapidly expanding, but astronomers can't agree upon how fast

EXPLORE THE MILKY WAY

Take **All About Space's** sightseeing tour of our galaxy
and explore the sights hidden within

Reported by Dave Eagle

It's easy to forget the true beauty and splendour of the Milky Way galaxy. With acres of countryside being torn down in favour of cities, the change in our planet's landscape can only really mean one thing: light pollution. This yellow-orange hue plagues many astronomers, washing out the stunning gems that our night sky has to offer, with only the brightest objects managing to shine through the haze. With the added appearance of the Moon, it can be extremely difficult to get any observing done that a stargazer feels satisfied with. The fainter and somewhat delicate beauty of our Milky Way galaxy simply can't compete.

Leaving behind the dazzling bright lights on a Moonless night, our galaxy will be less obscured. Allowing your eyes to take 20 minutes to adjust to the darkness, what you'll see will be a faint band of light, akin to a backlit cloud, snaking its way through a backdrop of stars. Your eyes alone can't resolve the Milky Way into individual stars, but that just makes our galaxy all the more alluring when it comes to hunting for the galactic treasures hidden in the Orion Spur - the section of the spiral arm where we live.

Which sections of the Milky Way you're able to see really depends on your location, as well

as the time of year. Throughout July, for example, those in the Southern Hemisphere will find the centre of the Milky Way overhead, its silvery band running from the southwestern horizon to the northeast. Meanwhile, in the Northern Hemisphere, the centre of the Milky Way is low in the southern sky, its dusty path sweeping upwards in an arch across the eastern sky through to the northern horizon. What's more, some of the Milky Way appears quite mottled, with brighter parts appearing as bursts of star-concentrated clouds interspersed with holes, or clouds of interstellar dust blocking our view of the stars beyond.

What's great about the Milky Way is that you don't really need any optical aid to take in its true beauty. A very dark site and your eyes alone can allow you to take in the stunning expanse of our galaxy in all its glory. However, a sweep of a pair of binoculars with magnifications starting at 7x50 or 10x50, all the way up to the slew of a telescope can help you to resolve its thousands of stars, along with the gems that you can find in its dusty path. Before you begin our tour of the Milky Way, remember that you're in a unique position to observe a galactic structure from the inside out. With this in mind, we hope you enjoy our observer's guide to our galaxy.

Getting the best views of the Milky Way

You'll need...

- ✓ Moonless night
- ✓ Dark skies with no light pollution
- ✓ Naked eye, binoculars or a telescope

Don't forget

It's difficult to observe the Milky Way in the spring from the Northern Hemisphere since it is very low on the horizon.

The summer Milky Way

Despite the shortage of night hours, the centre of our galaxy takes centre stage for a spellbinding sight during the warmer months

If you can observe from somewhere dark then the summertime Milky Way is one of the most stunning sights you will ever see in the night sky. The further south you go the better, because the brightest parts of the Milky Way are found in southern constellations such as Sagittarius (the Archer) and Scorpius (the Scorpion). If you are able to travel to locations such as Florida or the Canary Islands on holiday this summer and venture out to a dark site with no light pollution, you'll be stunned at how bright the Milky Way appears. It will look like shimmering clouds rising up from the horizon.

The first thing that you'll notice is that there is structure in the Milky Way - parts that are brighter, and some parts that are dark with barely any stars at all. These are called dark nebulae. They may look like holes in space, but they're not - they are huge clouds of cold gas and dust, cocoons inside which baby stars are being nurtured.

The very centre of our galaxy is in the direction of Sagittarius. We can't see it because the stars and dust and gas of the Milky Way in front of it block our view. As it climbs north the Milky Way enters the Summer Triangle, a name given to an asterism by the late Sir Patrick Moore, with three bright stars - Deneb of Cygnus (the Swan) Altair in Aquila (the Eagle) and Vega in Lyra (the Harp) - marking the corners.

1 North America Nebula (NGC 7000)

Constellation: Cygnus
Right Ascension: 20h 59m 17s
Declination: +44° 31' 44"
Magnitude: +4.0
Minimum optical aid: 10x50 binoculars or a four-inch telescope

Most objects in the night sky only look tenuously like the things they're named after, but the North America Nebula is the spitting image of the continent - it even has a curved gap that resembles the Gulf of Mexico. In reality it is an emission nebula approximately 1,600 light years away that is forming stars. It is bright, but large and diffuse, so despite being magnitude 4.0 it is very difficult to see with the naked eye, and ideally you need to view it through an instrument with a field of view of at least three degrees to encompass it all: 10x50 binoculars or a four-inch 'scope should do the trick.

2 Messier 26

Constellation: Scutum
Right Ascension: 28h 45m 00s
Declination: -9° 24' 00"
Magnitude: +8.0
Minimum optical aid: Six-inch telescope

This is an open cluster, which is a loose grouping of young stars that formed together. It is 5,003 light years away, but can be difficult to spot amid the crowded star fields of the Milky Way. In a telescope at high-power magnification, you will be able to resolve up to 25 stars. Look closely and you may also be able to make out the long lanes of dark nebulae around the cluster.

3 The Swan Nebula (Messier 17)

Constellation: Sagittarius
Right Ascension: 18h 20m 26s
Declination: -16° 10' 36"
Magnitude: +6.0
Minimum optical aid: Four-inch refractor or five-inch reflector

Near Sagittarius' border with the constellation Scutum lies this emission nebula, which is another star-forming zone and one of the best in the sky, but because it is so low when seen from Britain, it loses some of its splendour. It is sometimes called the Omega Nebula because in a modest telescope at low magnification it looks a bit like a ghostly Greek letter Omega.

4 Trifid Nebula (Messier 20)

Constellation: Sagittarius
Right Ascension: 18h 02m 23s
Declination: -23° 01' 48"
Magnitude: +6.3
Minimum optical aid: Five-inch telescope

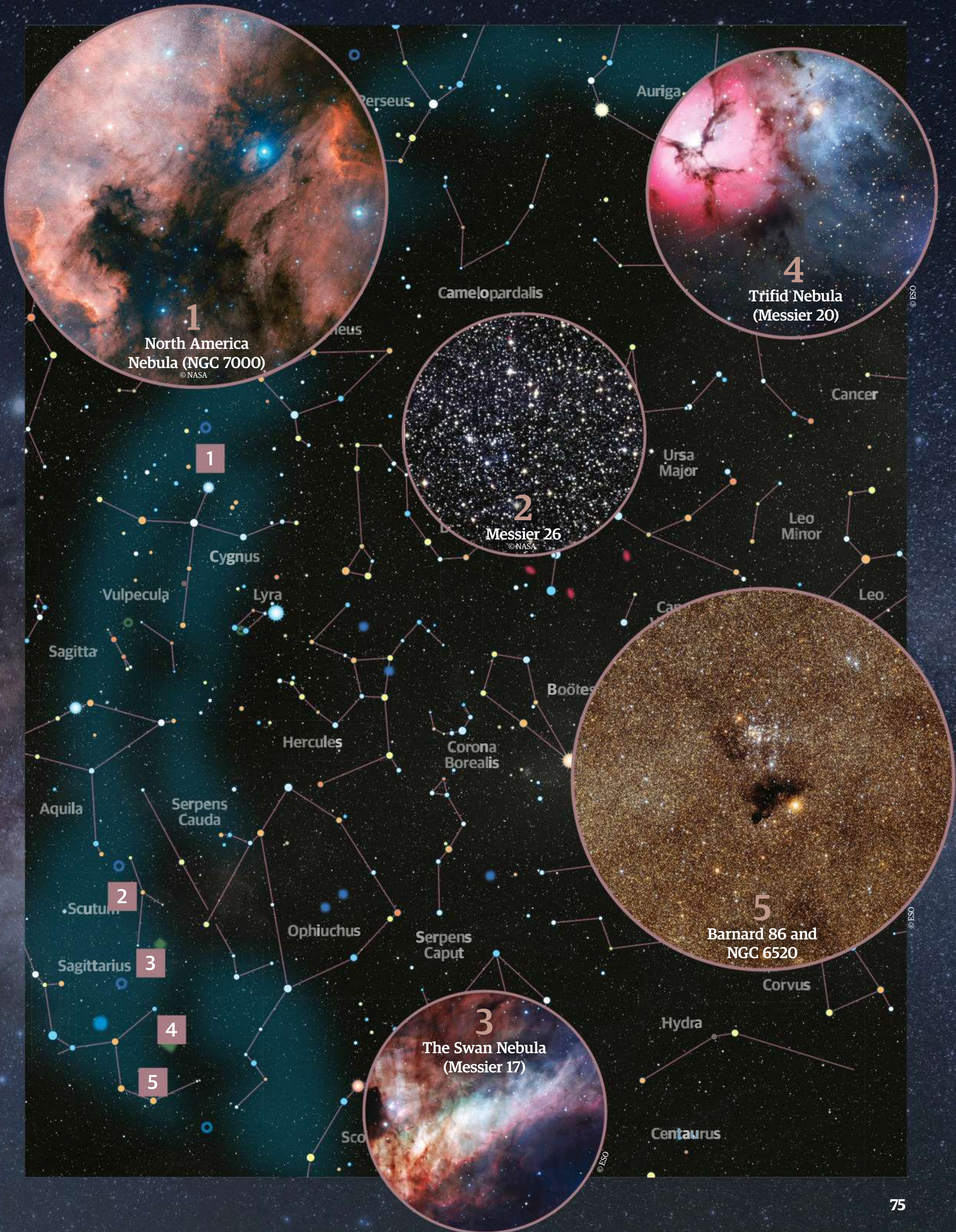
The Trifid Nebula was named by Sir John Herschel, son of William, who saw the nebula divided into three lobes by dark dust lanes - there are actually four lobes. The Trifid is a mixture of three types of nebula: an emission nebula (the redder areas), a reflection nebula (the blue regions) and dark nebulae that divide the lobes. Emission nebulae glow when heated by hot stars, while reflection nebulae reflect the light of bright stars.

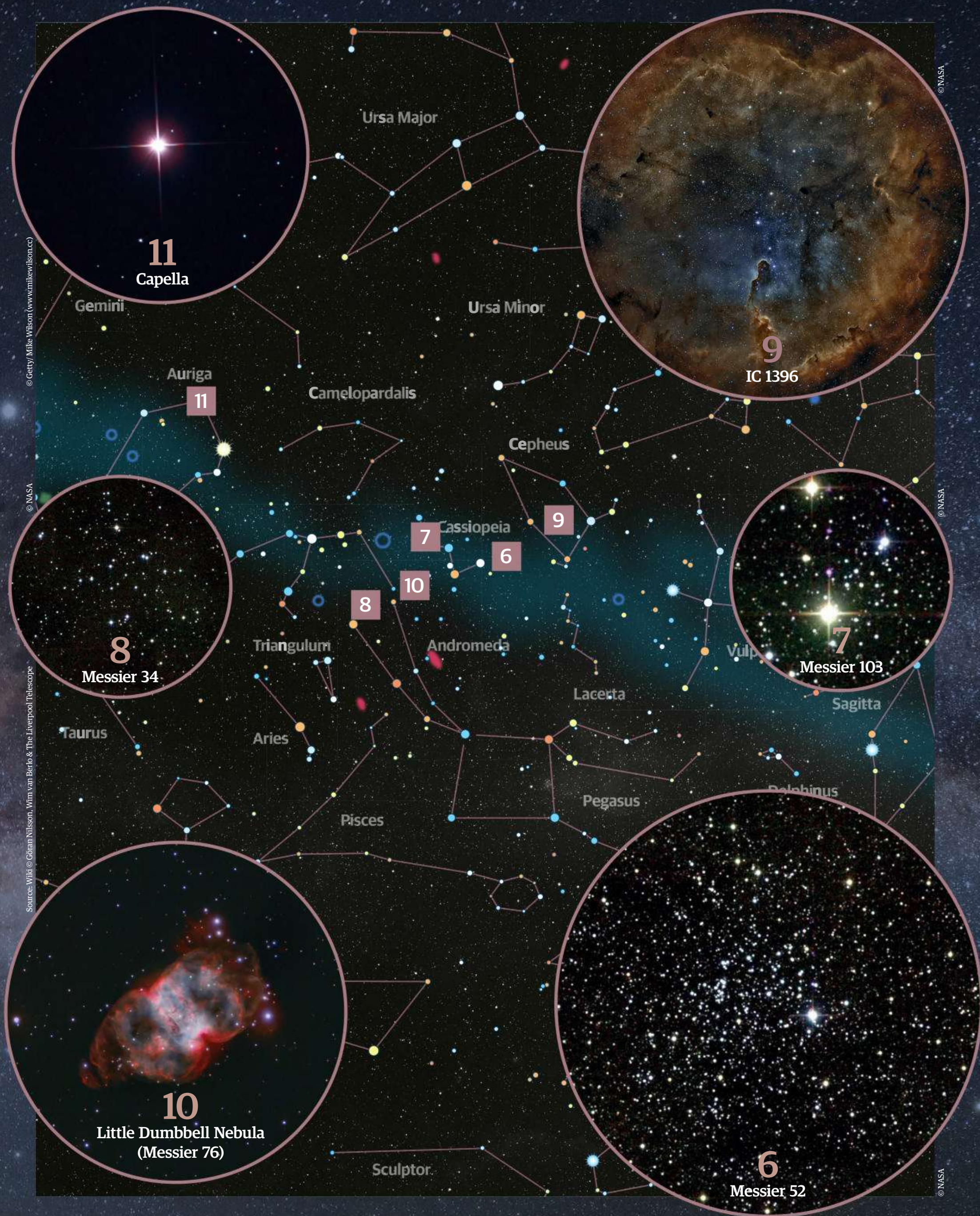
5 Barnard 86 and NGC 6520

Constellation: Sagittarius
Right Ascension: 18h 03m 48s
Declination: -27° 53' 00"
Magnitude: +9.0 (NGC 6520)
Minimum optical aid: Four-inch refractor or five-inch reflector

Barnard 86 is a classic example of a dark nebula, made of gas clouds filled with impenetrable black dust. It lies next to the open cluster NGC 6520 to the east. Try observing the pair together through your telescope using a magnification of 100x.

“The brightest parts are found in southern constellations such as Sagittarius and Scorpius”





The autumn night sky

As the leaves fall from the trees, the constellations of our summer galaxy also fall away to give way to those of the cooler months

Moving upwards away from the summer constellations of Cygnus and below, the Milky Way begins to lose some of its lustre as it starts to thin out compared to the densely star-packed region around the galaxy's centre. It is still impressive to see though, especially if you can get out to a dark-sky site in order to observe this shimmering belt of stars.

During the autumn our Milky Way moves through the constellations of Perseus, Cepheus and the familiar W-shape of Cassiopeia. Not all of the constellations of the summer have disappeared though – the likes of Cygnus and Aquila are still on show, offering observers in the Northern Hemisphere a selection of summer nebulae and star clusters. Autumn is the time to seek out open star clusters in our galaxy, which glow extremely brightly like gems in the night sky. Obviously astronomy is best done under night skies untouched by light pollution and in a Moonless sky, but if you're an urban dweller who is unable to get out to the countryside, open clusters are still easily visible from locations with moderate town haze. Star clusters stand out much better than fuzzy and often dim nebulae. Not only that, but the Milky Way laces through constellations that are high up in the sky, meaning that you won't need to peer through a horizon touched by artificial lighting in order to get a good look at our galaxy.

6 Messier 52

Constellation: Cassiopeia
Right Ascension: 23h 24m 48s
Declination: +61° 35' 36"
Magnitude: +5.0
Minimum optical aid: 10x50 binoculars

This open cluster displays one of the biggest problems of the Milky Way. Because we are looking into the galaxy's spiral arms, which are full of dust, the light of objects in the Milky Way can be dimmed by that dust, which makes it hard to calculate their distance. The open cluster Messier 52 lies between 3,000 and 7,000 light years from us, but even though interstellar dust is blocking some of the light, it is still an easy binocular object.

7 Messier 103

Constellation: Cassiopeia
Right Ascension: 01h 33m 20s
Declination: +60° 42' 00"
Magnitude: +7.4
Minimum optical aid: Four-inch refractor or five-inch reflector

Another open cluster, Messier 103 contains about 40 stars, including a red giant, which is an evolved star reaching the end of its life. This is a very rare sight in an open cluster of young stars. To find M103, locate the bottom-left star of Cassiopeia's 'W', called Ruchbah, or Delta Cassiopeiae, and the cluster is about a degree northeast.

8 Messier 34

Constellation: Perseus
Right Ascension: 02h 42m 10s
Declination: +42° 46' 00"
Magnitude: +5.5
Minimum optical aid: 10x50 binoculars and four- or five-inch telescopes

If you look two binocular fields north of Algol, the brightest star in Perseus and a variable too, you'll come across the open star cluster Messier 34. Binoculars will not resolve any of the 90 member stars, but if you direct a small four-inch telescope its way, the stars will start to pop out.

9 IC 1396

Constellation: Cepheus
Right Ascension: 21h 39m 00s
Declination: +57° 30' 00"
Magnitude: +10.0
Minimum optical aid: CCD camera

In order to see IC 1396, a star-forming region that forms part of the Cepheus Bubble, you'll need a CCD camera. Being incredibly faint, you would find it difficult to pick up this nebula and its darker regions, known as Bok globules, with binoculars or a telescope alone. Imaging IC 1396 will reveal a hot supergiant illuminating its centre and yellow supergiant Mu Cephei at its edge.

10 Little Dumbbell Nebula (Messier 76)

Constellation: Perseus
Right Ascension: 01h 42m 24s
Declination: +54° 34' 31"
Magnitude: +10.1
Minimum optical aid: Six- to eight-inch telescope

Taking on an appearance similar to that of the Dumbbell Nebula, Messier 27, the pint-sized Little Dumbbell Nebula will require a telescope of at least six inches for comfortable observing. Point your instrument to Phi Andromedae, a prominent blue star, then look slightly east and you will come across the nebula.

11 Capella (Alpha Aurigae)

Constellation: Auriga
Right Ascension: 05h 16m 41s
Declination: +45° 59' 53"
Magnitude: +0.08
Minimum optical aid: Naked eye

It's not too difficult to find the rich yellow-white star Capella, the sixth-brightest star in the sky in the constellation of Auriga. Capella is actually a star system of four stars, which can be split into two stars. The yellowish tint of this star is much more apparent in a daytime sky with its contrast against the blue.

Our winter galaxy

We reach the outer edge of the Milky Way as we hit the darker days of the year

During this much colder time of the year, we can enjoy the longer hours of night for extended tours and observations of targets in the night sky. Sadly, winter isn't the best time of year to observe the Milky Way as our planet only looks towards the sparser regions of our galaxy - the outer portion of the disc.

That's not to say that the Milky Way doesn't hold a degree of wonder during the winter. Stars still clump together in the splash of white that's characteristic of our galaxy as it laces through the constellations Canis Major (the Great Dog), Monoceros (the Unicorn), Orion (the Hunter) and Puppis (the Poop Deck), bringing with it a spectacular selection of objects for stargazers to enjoy.

12 Messier 47

Constellation: Puppis
Right Ascension: 07h 36m 00s
Declination: -14° 30' 00"
Magnitude: +4.2
Minimum optical aid: Naked eye

It is possible to view the coarse brightness of the open star cluster M47 with the naked eye under very good night sky conditions. However, the 50 stars it contains won't be resolved so easily without the assistance of a pair of binoculars or a telescope. The swarm of young stars takes over a portion of the sky around the same size as the full Moon.

13 Rosette Nebula and NGC 2244

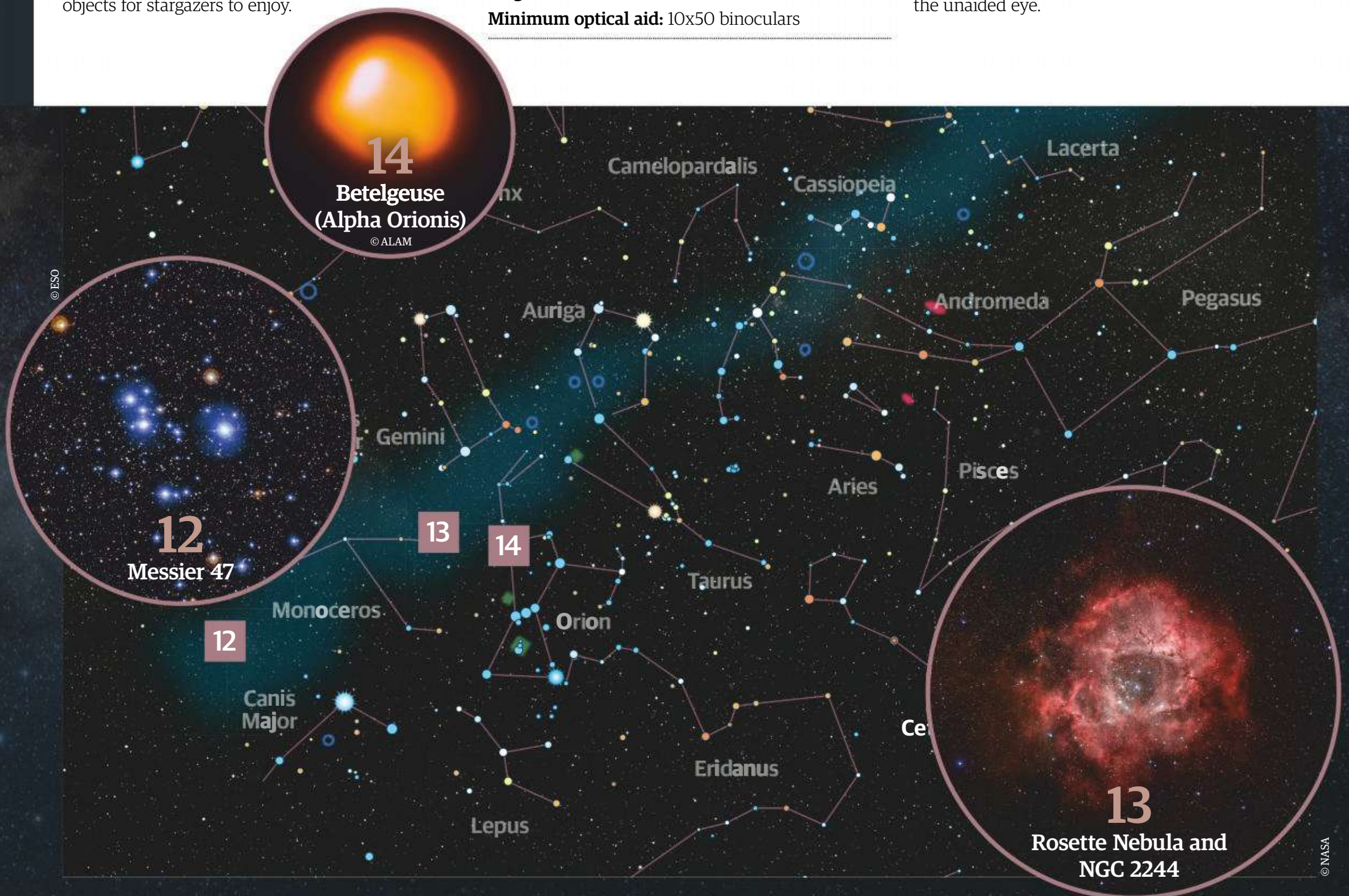
Constellation: Monoceros
Right Ascension: 06h 33m 45s
Declination: 04° 59' 54"
Magnitude: +9.0 (Rosetta Nebula) +5.0 (NGC 2244)
Minimum optical aid: 10x50 binoculars

The Rosette is a giant ring nebula in the constellation of Monoceros, and NGC 2244 is a young star cluster that has emerged from that nebula. Spotting the cluster is easy in binoculars or a small telescope, but seeing the nebula visually is very difficult without a large telescope, a dark countryside sky and an ultra-high contrast filter.

14 Betelgeuse (Alpha Orionis)

Constellation: Orion
Right Ascension: 05h 55m 10s
Declination: +07° 24' 26"
Magnitude: +0.2 to +1.2
Minimum optical aid: Naked eye

It's not too difficult to spot its proud orange-red hue, even if it does appear to be dimming at present. Red supergiant Betelgeuse is a variable star, meaning that its brightest fluctuates. You can also use a telescope or binoculars to view Betelgeuse, but you will see nothing more than you can with the unaided eye.



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A: 20 B: 100 C: 110

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STARGAZER

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Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

What's in the sky?



Source: Wikipedia Commons © Miguel Garcia

31 JAN



The Beehive open star cluster (Messier 44) is well placed for observation in Cancer

14 FEB



Mercury reaches its highest point in the evening sky, shining at magnitude -0.6

18 FEB



Conjunction between the Moon and Mars in Sagittarius

18 FEB



The Moon and Mars make a close approach, passing within 0°45' of each other

19 FEB



Conjunction between the Moon and Jupiter in Sagittarius

19 FEB



The Moon and Jupiter make a close approach, passing within 0°55' of each other in Sagittarius



Source: Wikipedia Commons © Juliancolton

19 FEB



Bode's Galaxy (Messier 81) is well placed for observation in Ursa Major



Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

**8
FEB**



The Moon and Messier 44 will make a close approach within 1°17' of each other in Cancer

**10
FEB**



Mercury is at its greatest elongation east in the evening sky, shining at -0.6

**10
FEB**

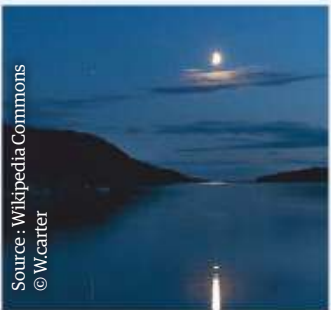


Mercury reaches dichotomy in the evening sky, shining at magnitude -0.6

**18
FEB**



Mars and open cluster NGC 6530 make a close approach in Sagittarius



Source: Wikipedia Commons
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Source: Wikipedia Commons
© Rbruels



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Naked eye



Binoculars



Small telescope



Medium telescope



Large telescope

Owners' Workshop



An insight into the study and exploration of the
David M. Harland





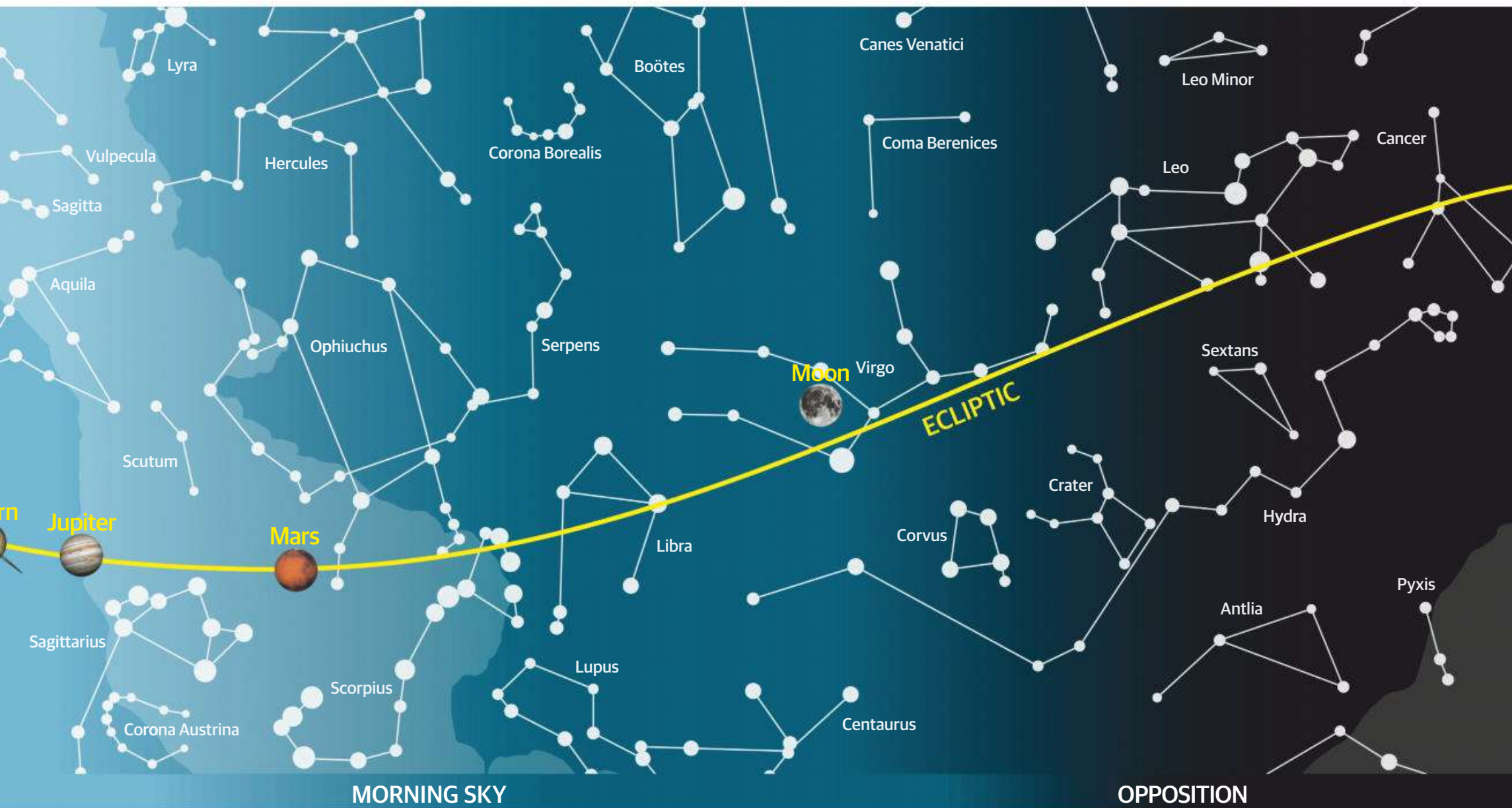
Moon calendar

* The Moon does not pass the meridian on 8 February

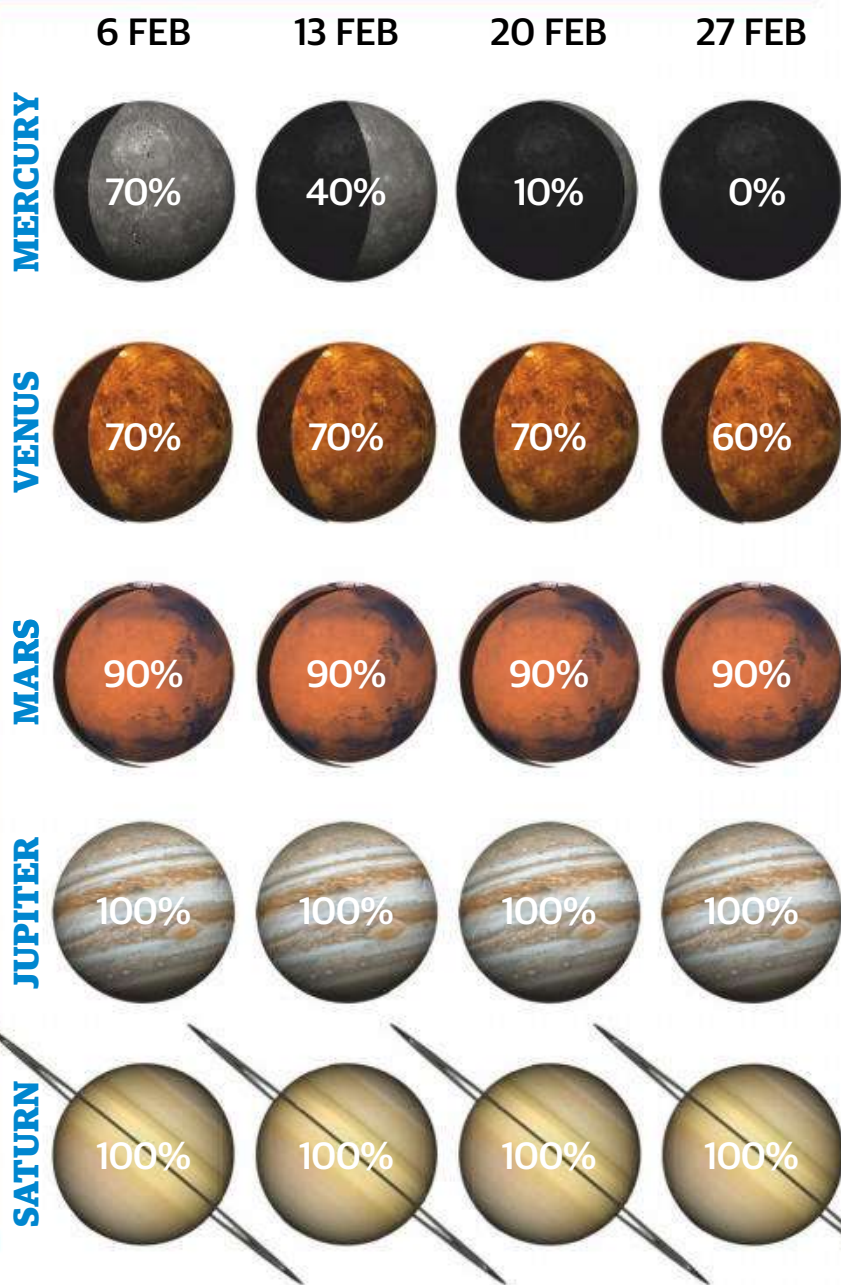
30 JAN  28.2% ☀ 10:15 🌑 22:42	31 JAN  37.3% ☀ 10:31 🌑 23:49	1 FEB  46.9% ☀ 10:49 🌑 ---	2 FEB FQ  56.9% 🌑 00:56 ☀ 11:08
6 FEB  92.4% 🌑 05:31 ☀ 13:31	7 FEB  97.4% 🌑 06:29 ☀ 14:36	8 FEB  99.9%* 🌑 07:17 🌑 15:52	9 FEB FM  99.8% 🌑 07:55 ☀ 17:15
13 FEB  79.7% 🌑 09:34 ☀ 22:56	14 FEB  69.2% 🌑 09:56 ☀ ---	15 FEB TQ  57.9% ☀ 00:17 🌑 10:20	16 FEB  46.5% ☀ 01:36 🌑 10:48
20 FEB  9.8% ☀ 05:50 🌑 13:52	21 FEB  4.6% ☀ 06:29 🌑 14:56	22 FEB  1.4% ☀ 07:01 🌑 16:03	23 FEB NM  0.2% ☀ 07:25 🌑 17:11
27 FEB  13.9% ☀ 08:37 🌑 21:37	% Illumination ☀ Moonrise time 🌑 Moonset time FM Full Moon NM New Moon FQ First quarter TQ Third quarter		

All figures are given for 00h at midnight (local times for London, UK)

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

All rise and set times are given in GMT

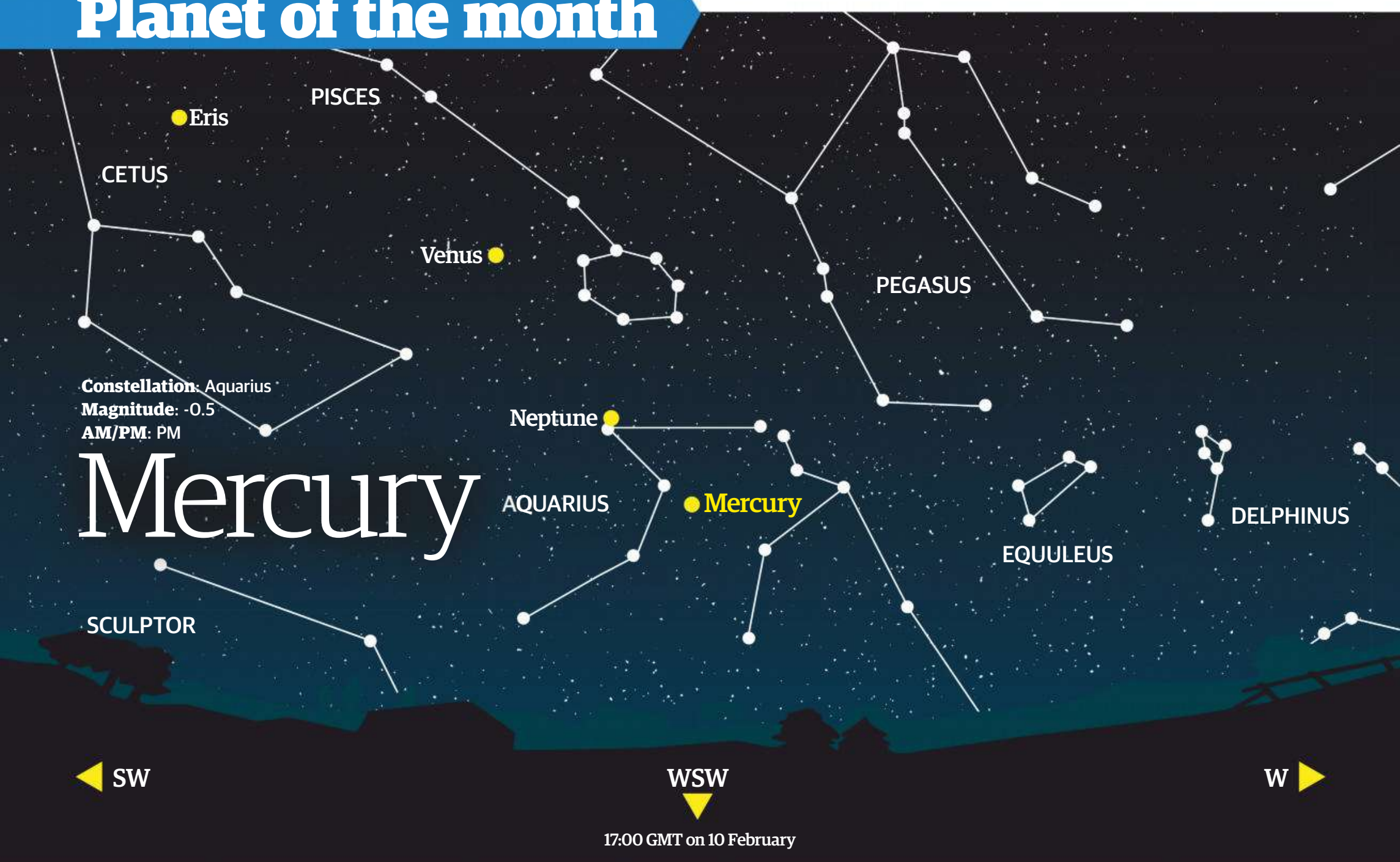
	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	30 JAN	21h 40m 51s	-15° 26' 11"	Capricornus	-1.0	08:22	17:48
	6 FEB	22h 22m 15s	-10° 31' 29"	Aquarius	-0.9	08:09	18:29
	13 FEB	22h 48m 37s	-06° 05' 03"	Aquarius	-0.3	07:45	18:51
	20 FEB	22h 48m 19s	-04° 14' 08"	Aquarius	2.1	05:17	13:18
	27 FEB	22h 24m 17s	-06° 00' 15"	Aquarius	5.2	06:25	17:32
VENUS	30 JAN	23h 22m 04s	-05° 08' 59"	Aquarius	-4.1	09:08	20:24
	6 FEB	23h 52m 01s	-01° 30' 47"	Pisces	-4.1	08:52	20:44
	13 FEB	00h 21m 25s	+02° 09' 08"	Pisces	-4.1	08:36	21:05
	20 FEB	00h 50m 28s	+05° 46' 47"	Pisces	-4.2	08:19	21:25
	27 FEB	01h 19m 18s	+09° 18' 22"	Pisces	-4.2	08:01	21:44
MARS	30 JAN	17h 06m 48s	-22° 50' 17"	Ophiuchus	1.4	04:35	12:29
	6 FEB	17h 27m 30s	-23° 16' 57"	Ophiuchus	1.3	04:31	12:19
	13 FEB	17h 48m 23s	-23° 33' 44"	Sagittarius	1.3	04:26	12:10
	20 FEB	18h 09m 23s	-23° 40' 26"	Sagittarius	1.2	04:21	12:03
	27 FEB	18h 30m 28s	-23° 36' 55"	Sagittarius	1.1	04:14	11:56
JUPITER	30 JAN	18h 56m 19s	-22° 45' 41"	Sagittarius	-1.9	06:24	14:18
	6 FEB	19h 02m 51s	-22° 37' 04"	Sagittarius	-1.9	06:02	13:58
	13 FEB	19h 09m 10s	-22° 27' 47"	Sagittarius	-1.9	05:39	13:38
	20 FEB	19h 15m 15s	-22° 17' 59"	Sagittarius	-1.9	05:17	13:18
	27 FEB	19h 21m 03s	-22° 07' 53"	Sagittarius	-2.0	06:25	14:43
SATURN	30 JAN	19h 45m 49s	-21° 11' 38"	Sagittarius	0.6	07:03	15:18
	6 FEB	19h 49m 13s	-21° 03' 28"	Sagittarius	0.6	06:38	14:55
	13 FEB	19h 52m 30s	-20° 55' 18"	Sagittarius	0.6	06:12	14:31
	20 FEB	19h 55m 40s	-20° 47' 13"	Sagittarius	0.6	05:47	14:08
	27 FEB	19h 58m 42s	-20° 39' 21"	Sagittarius	0.7	05:22	13:44



This month's planets

If you're not a fan of getting an early start, you're in luck: many of the Solar System's offerings are visible in the evening

Planet of the month



Mercury is our Planet of the Month this issue because it won't appear as bright in the evening sky again for the rest of the year. Mercury is considered by many astronomy enthusiasts and professional planetary astronomers to be a 'forgotten planet', one of the worlds which has been ignored in favour of more exciting and picturesque worlds such as mighty Jupiter, ringed Saturn and the Red Planet, Mars. They may have a point; it is a fascinating world in its own right. One day a probe - heavily armoured against the nearby Sun's intense radiation, which is just as lethal to electronics as it would be to any astronaut crews sent to explore its rugged surface - will land on Mercury and send back breathtaking images of its heat-blistered landscape, but until then we will have to make do with

images taken from orbit, showing its own huge craters, impact basins and mountains.

Poor Mercury also has a reputation for being 'difficult' and hard to see, and it's true that many amateur astronomers have either failed to find it or even given up trying altogether. In fact, Mercury is easily visible to the naked eye if you know exactly where and when to look for it, and this month you can use a much brighter planet as a signpost to point you right to it. Once you have spotted Mercury in the sky your eye will go straight back to it

Throughout this month Mercury will be an 'evening star', visible in the southwest as a copper-hued 'star' as soon as the sky begins to darken. However, it will be quite low down, so if you have any obstructions - trees, hills or

buildings - in that direction they might hide it from you, so make sure to find an observing spot with a clear view and a low southwestern horizon to go Mercury-spotting from.

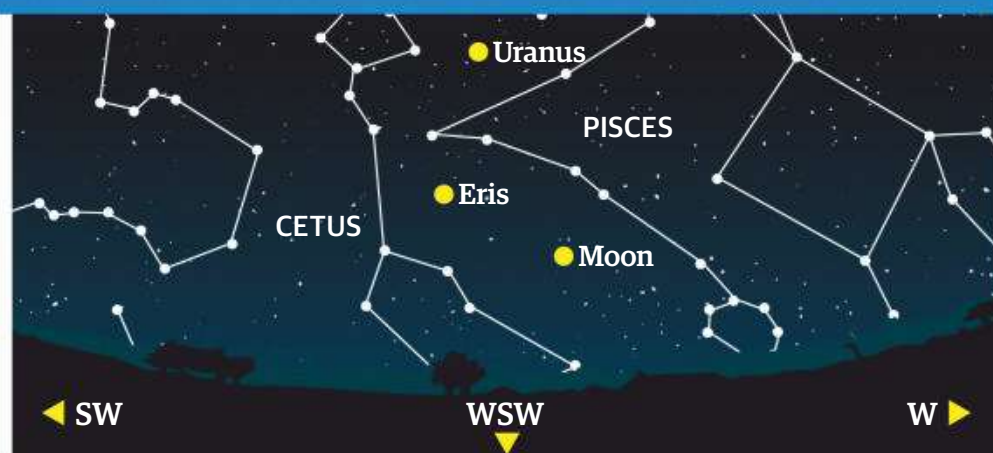
If Mercury doesn't show itself right away, don't worry. You have to have pretty good eyesight to spot it early. If you're still struggling to pin it down after a while, use Venus, which will be shining higher in the sky further over to the east, and will be so dazzlingly bright it's impossible to miss: just look to the lower right of Venus at around a 45-degree angle, and there you'll see Mercury.

Mercury will be at its best on the evening of 10 February, but after that it will quickly begin to fall back towards the Sun, losing a little height - and brightness - each night before vanishing into the glow of dusk before the end of the month.



This month's planets

Venus 19:00 GMT on 26 February



Constellation: Pisces

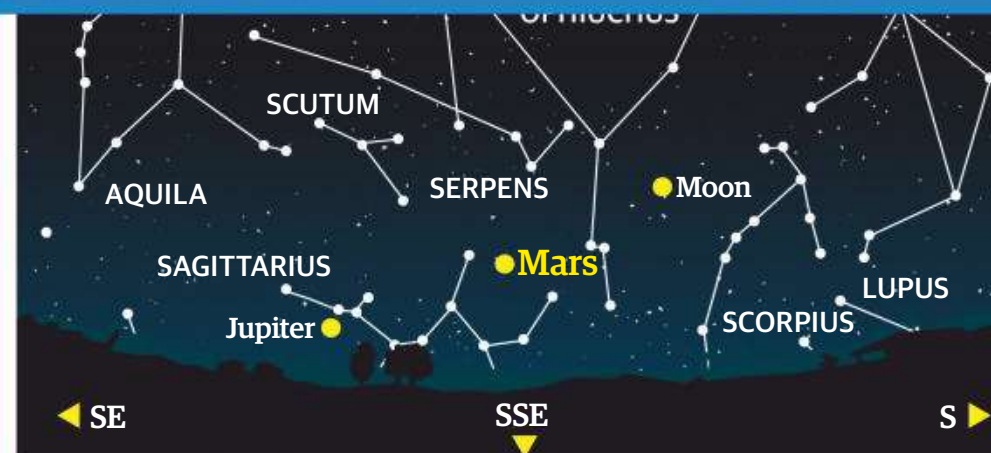
Magnitude: -4.2

AM/PM: PM

Venus will pop out as soon as the sky begins to darken after sunset, shining to the upper left of fainter

Mercury. An hour after sunset Venus will look like a lovely silvery-blue spark in the southwest. Look out for the crescent Moon shining beneath Venus after dark on the evening of 26 February.

Mars 06:00 GMT on 17 February



Constellation: Sagittarius

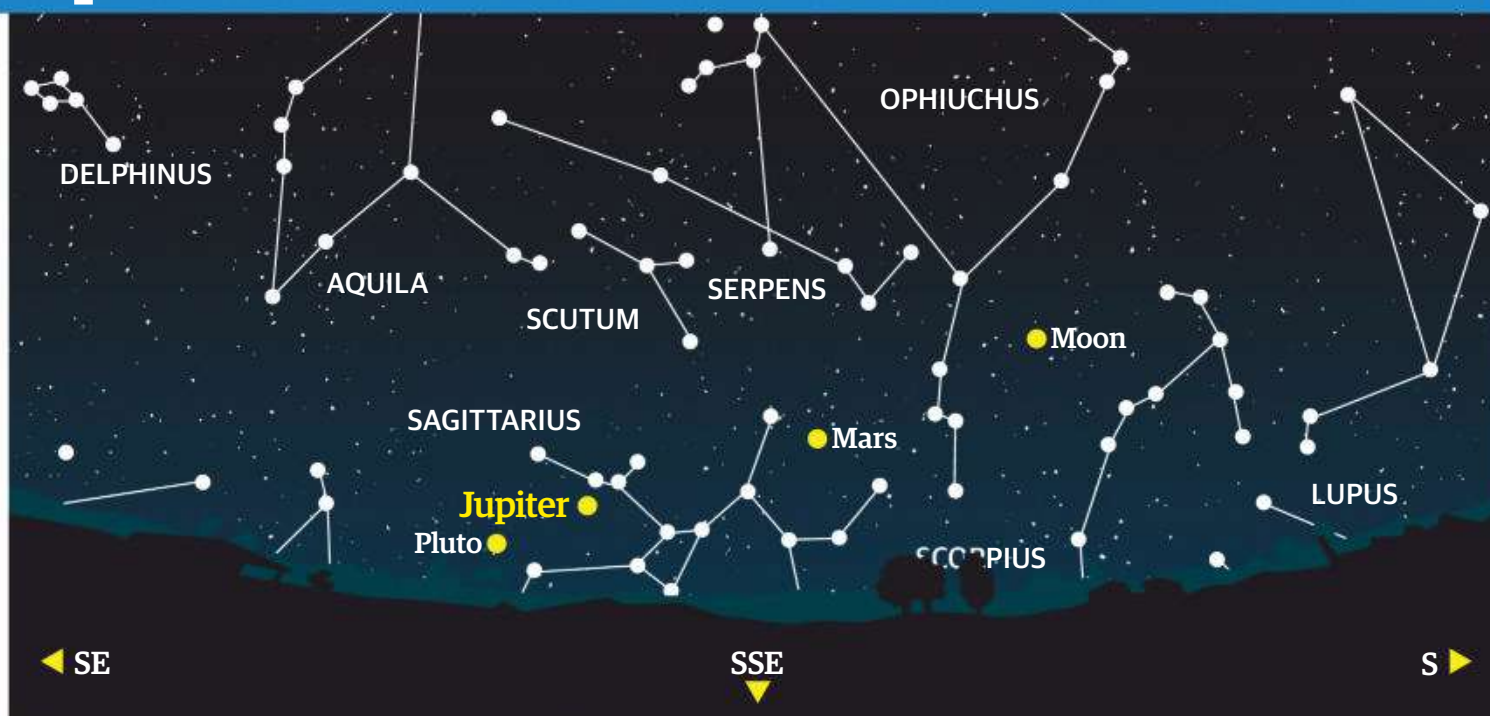
Magnitude: 1.2

AM/PM: AM

Mars is just another bright star in the morning sky, albeit a distinctly orange-hued one. If you have a pair

of binoculars train them on Mars on the evening of 17 February and you'll be able to see Mars passing between two of the most famous deep-sky objects, the Trifid Nebula and the Lagoon Nebula.

Jupiter 06:30 GMT on 17 February



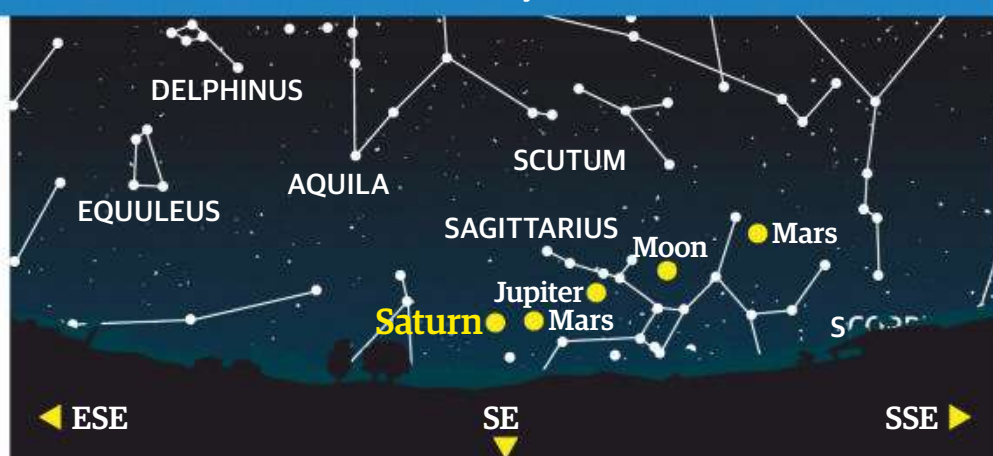
Constellation: Sagittarius

Magnitude: -1.9

AM/PM: AM

Although it won't be as obvious to the eye as it was a few months ago, this will still be another good month for Jupiter-spotters, with the largest planet in our Solar System visible to the naked eye as a 'morning star' low in the east before sunrise, sandwiched between much fainter Saturn on its left and fainter Mars on its right. Shining at magnitude -1.9, Jupiter will be brighter than the brightest star in the sky, and brighter than any other planet except Venus. As the month changes it will rise in the southeast an hour before the Sun and after that will move further from it each day.

Saturn 06:30 GMT on 19 February



Constellation: Sagittarius

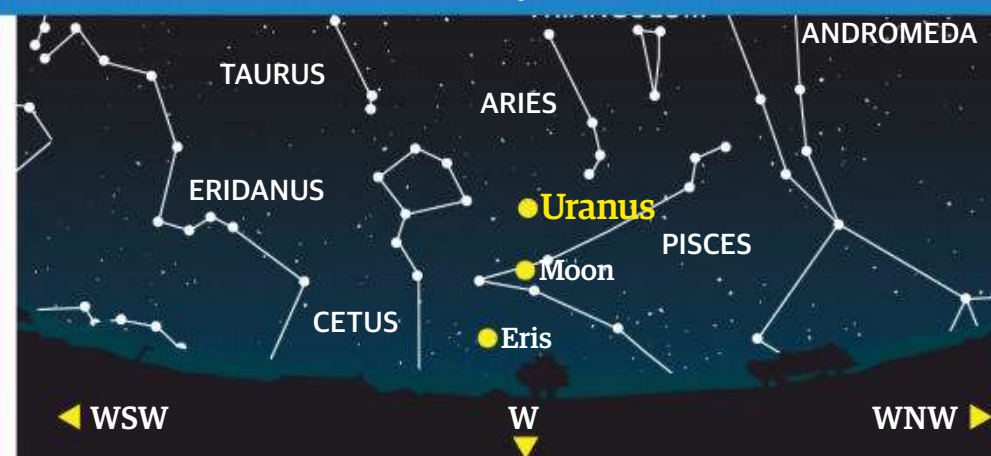
Magnitude: 0.6

AM/PM: AM

Saturn will be a morning object this month, but not that easy to see as it will rise only an hour or so

before the Sun. Its magnitude of 0.6 makes it sound very impressive, and technically it will be almost as bright as Betelgeuse, but being trapped in the brightening dawn sky will make Saturn look a lot less obvious.

Uranus 22:30 GMT on 31 January



Constellation: Pisces

Magnitude: 5.8

AM/PM: PM

Uranus is an evening object this month, just hanging around in southern Pisces. At magnitude 5.8 it

is technically a naked-eye object, but in reality you'll only pick it out from all the stars behind and around it if you know that part of the sky like the back of your hand and know which of those 'stars' it actually is.



STARGAZER

© NASA

Top tip!

If you can't see Mare Orientale, try fitting a Moon filter to your telescope to dim the Moon. It will be easier to see.

Moon tour

Mare Orientale

One of the Moon's most incredible but elusive features peeks around its limb this month

This month's tour destination is, in the opinion of many Moon enthusiasts, the most spectacular feature on the surface of Earth's satellite. It resembles nothing less than an enormous archery target bullseye on the Moon - but frustratingly, we can't really see it.

We can see part of it - a hint of it - but this lunar feature is located just around the western limb of the Moon, so we only see its closest edge, and we can only see that when the Moon's wobble - or 'libration' - briefly tips it towards us. A few privileged people have seen it in all its glory: the Apollo astronauts flew over it and stared down at it with awe and wonder, but for the rest of us the only views we can enjoy are the images taken by satellites orbiting or space probes passing the Moon on their way to a distant world.

Mare Orientale - or the Eastern Sea - is a 327-kilometre (203-mile) wide dark sea, or mare, of frozen lava, surrounded by three concentric rings of crater-pocked mountains which make the whole feature more than 900 kilometres (560 miles) across. It is one of the youngest impact features on the Moon, blasted out of it around 3.8 billion years ago by an enormous asteroid more than 60 kilometres (37.3 miles) wide. In contrast, the asteroid that helped kill

off the dinosaurs was only ten kilometres (6.2 miles) wide. It's hard to imagine the enormous amount of energy released in that event. If time travel is ever invented, surely one of the most popular Moon destinations will be the day Mare Orientale was formed, so people can see the asteroid plummeting into the Moon, exploding with a blinding flash and blasting a gaping hole out of the lunar crust, leaving behind the enormous bullseye target we see today.

It's fascinating to imagine how different things would have been if that asteroid had struck the Moon on its Earth-facing side. Some think it would have affected the development of many of our cultures and religions. Today, during a full Moon, instead of us looking up at the gently smiling face of the 'Man in the Moon' we would instead see a huge eye, staring down at us from the sky, never blinking, never closing. And during a total lunar eclipse that

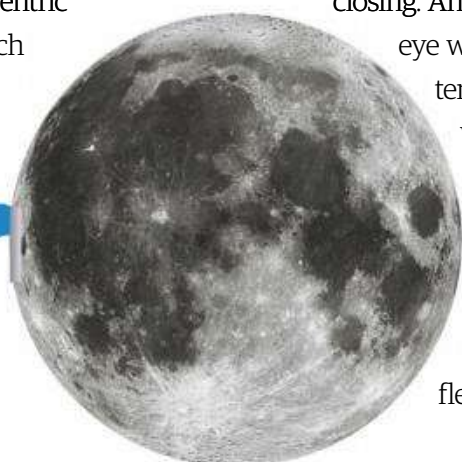
eye would appear red, bloodshot. How terrifying would that be? Surely we would now fear the Moon and cower under its gaze, rather than writing poetry or songs about it.

Because Mare Orientale is only ever visible for a brief time, any opportunity to catch even a fleeting glimpse of it is grasped by

lunar observers. This month the Moon's libration will woozily swing the western side of the Moon towards us most favourably on 10 February, when the Moon is full. That's when Mare Orientale and its surrounding rings of mountain will come into view, but only through a good pair of binoculars or preferably a telescope, and even then only as a mottled, light-and-dark area close to the lunar limb.

To find Mare Orientale, imagine the Moon's face as a clock face. Around 10 February when the Moon is full, Mare Orientale will be tilted towards us because the lunar libration will be at its most pronounced. Focus your binoculars or telescope towards the dark-floored crater Grimaldi, which can be found at the eight o'clock position. To the crater's lower left, right on the limb, you will see a mottled area - this is Mare Orientale and its mountains.

If you use a high-magnification eyepiece on Mare Orientale when it is presented to us at its very best you can see a surprising amount of detail around and within it, and there are lots of lunar charts and maps available online to help you identify them. Unfortunately, no matter how much you magnify the view you won't be able to see the feature's true 'bullseye' nature, but that's not the point. Just enjoy seeing something most sky-watchers, and many Moon observers, never manage to see.



Naked eye & binocular targets

Spring is on its way, so enjoy these winter-sky delights while you still can

Betelgeuse (Alpha Orionis)

This bright-orange star, marking the shoulder of Orion, the Hunter, is the ninth-brightest in the sky. It's a supergiant star, so big that it would stretch halfway to Jupiter if it replaced our own much smaller Sun. It lies 500 light years away.

Sirius (Alpha Canis Majoris)

The brightest star in the whole sky, Sirius shines with a beautiful, icy-blue light on winter evenings. Less than nine light years away, it is the fifth-closest star to the Sun. When low in the sky it flashes and sparkles like a jewel.

Orion's Belt

The three blue-white stars that form Orion's famous 'belt' might all look like they're the same distance away from us, but it's a celestial optical illusion. Alnilam, the middle star, is almost twice as far away as its neighbours Alnitak (left) and Mintaka (right).

Orion

Monoceros

Messier 41

Scan the sky directly beneath Sirius with a pair of binoculars and you'll find a small star cluster. Messier 41 is 2,316 light years away and contains around 8,000 stars. On a clear night with no Moon you might even see it with your naked eye as a smudge.

The Orion Nebula (Messier 42)

The middle star in Orion's 'sword' looks misty and blurry to the naked eye. Binoculars reveal the star to actually be a nebula, a glowing cloud of gas and dust, inside which new stars are being born. It is over 1,300 light years away.



NGC 2903

Source: Wikipedia Commons © Jschulman555

Deep sky challenge

Galaxy hunt in Leo

Spring is around the corner, but you can already enjoy some of its deep-sky delights

Spring is just around the corner, but if you're willing and able to stay up late on these still-chilly February evenings you can enjoy some of its deep-sky delights a little early.

Throughout this month the eastern sky will be dominated by the Sphinx-like shape of Leo, the Lion, with its famous 'sickle' asterism and bright stars Regulus and Denebola catching the eye. But if you train your telescope and look through Leo's fine mane of foreground stars, there are many fascinating things far behind it.

The spring sky belongs to galaxies, of course, and there are literally thousands of them stretched

across Leo and its neighbour, Virgo. But beyond the well-known 'celebrity' Messier list galaxies such as M95, M96 and M105 there are smaller, fainter and more distant island universes to explore through your best eyepiece. So close to bright Regulus it is almost overwhelmed by its glare, the dwarf galaxy Leo 1 is a challenge for large telescopes - any light pollution or moonlight will wash it from the sky. In contrast, almost any telescope will show the beautiful spiral arms of galaxy NGC 2903.

So, before spring arrives, and its lighter nights too, swing your telescope around to Leo and go deep into the deep sky. You'll be glad you did!



NGC 4147

© NASA/ESA Hubble Space Telescope



Source: Wiki ©Scott AnttilaAnttiler

1 EGB 6

This tenth-magnitude planetary nebula is only visible in large telescopes. At high magnification and under perfect conditions, you'll see hints of a 'crescent' of brighter material along its outer edge.

2 LEO I

This tenth-magnitude elliptical galaxy is almost lost in the glare of bright Regulus. However, even a medium-aperture telescope will show it as a small, lens-shaped, mottled smudge.

3 NGC 2903

This lovely spiral galaxy is presented to us at an oblique angle. Under a dark sky a large telescope will show its bright centre and two spiral arms curving away from it gracefully.

4 NGC 3872

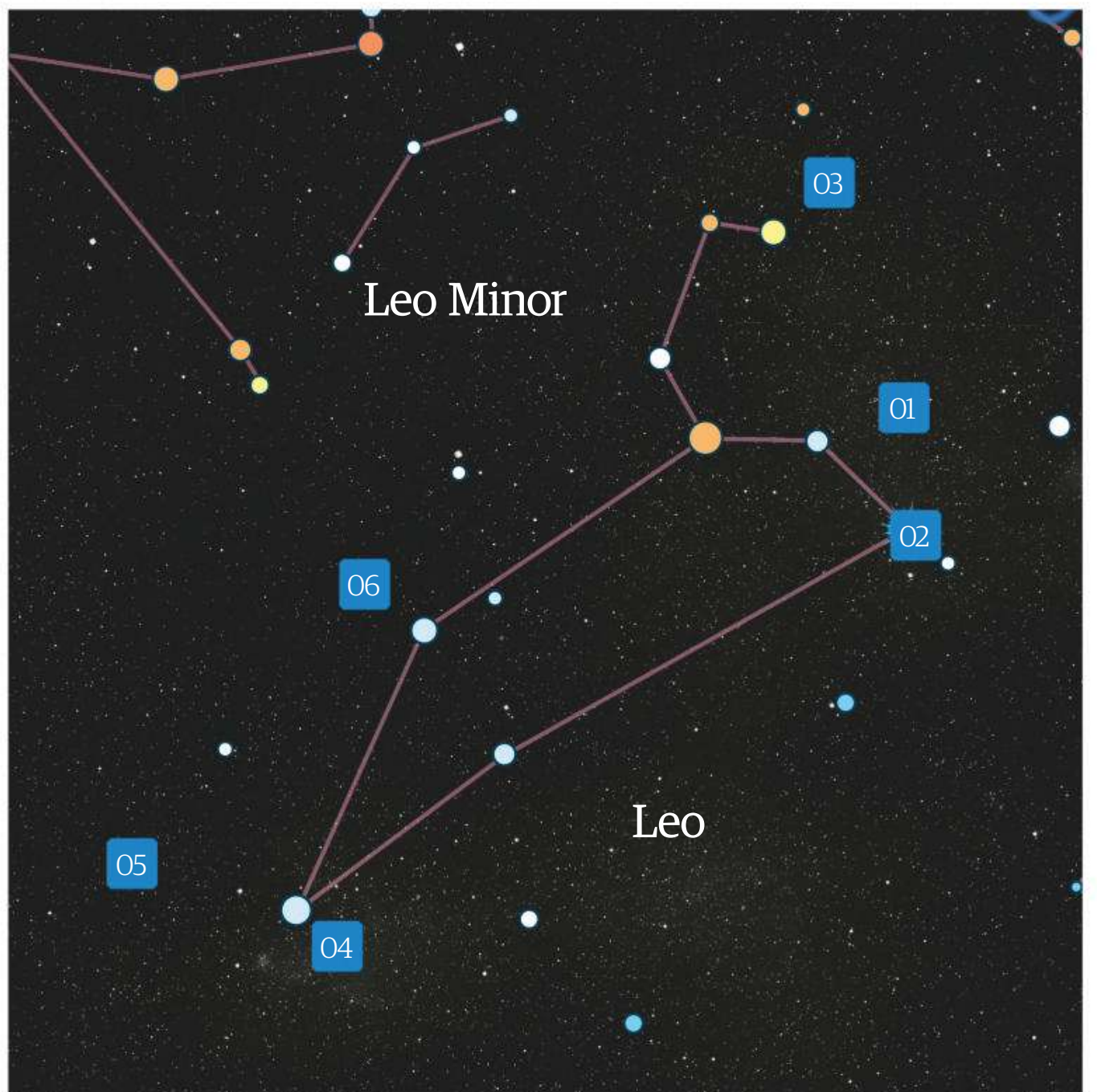
This 11th-magnitude elliptical galaxy is just a tiny, dim, featureless smudge even in large telescopes, but the joy of observing it lies in knowing it is 150 million light years away.

5 NGC 4147

At tenth magnitude, this ancient globular cluster, 63,000 light years from Earth, is visible even in small telescopes as an out-of-focus star. Larger instruments reveal its mottled core.

6 LEO II

This elliptical dwarf galaxy is almost 12th magnitude, so you'll need a large telescope, a perfect sky and no hint of light pollution to see it through a high-magnification eyepiece.





The Northern Hemisphere

There's a chill in the air as February rolls around, offering clear, crisp sights

The 'Dog Star' Sirius starts to dip low towards the horizon, below and to the left of Orion (the Hunter). Meanwhile, Taurus (the Bull) can be spotted on the other side of the famous Belt of Orion, and Gemini (the Twins) is high in the south. You'll be able to locate the twins with ease thanks to its member stars Castor and Pollux. Gemini also hosts some beautiful deep-sky targets, including the Medusa Nebula (Abell 21), the Eskimo Nebula (NGC 2392) and open cluster Messier 35. Coming to the end of winter, you'll still be able to locate the Hyades cluster in Taurus, which sits close to the Bull's eye, Aldebaran, with the naked eye, as well as the Pleiades, or Seven Sisters, also known as Messier 45.

Using the sky chart

This chart is for use at 22:00 (GMT) mid-month and is set for 52° latitude.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.



Magnitudes

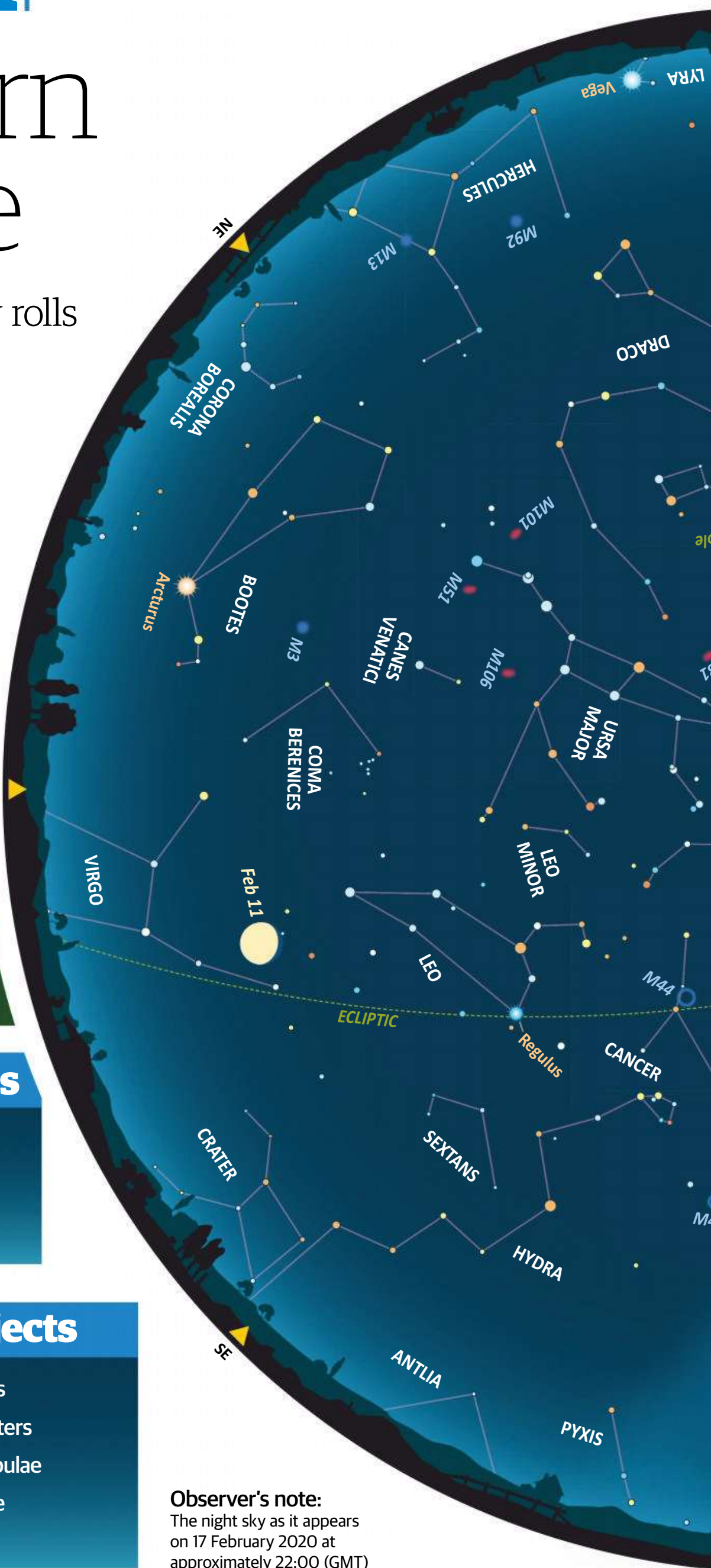
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- | | |
|-------|-----|
| • O-B | • G |
| • A | • K |
| • F | • M |

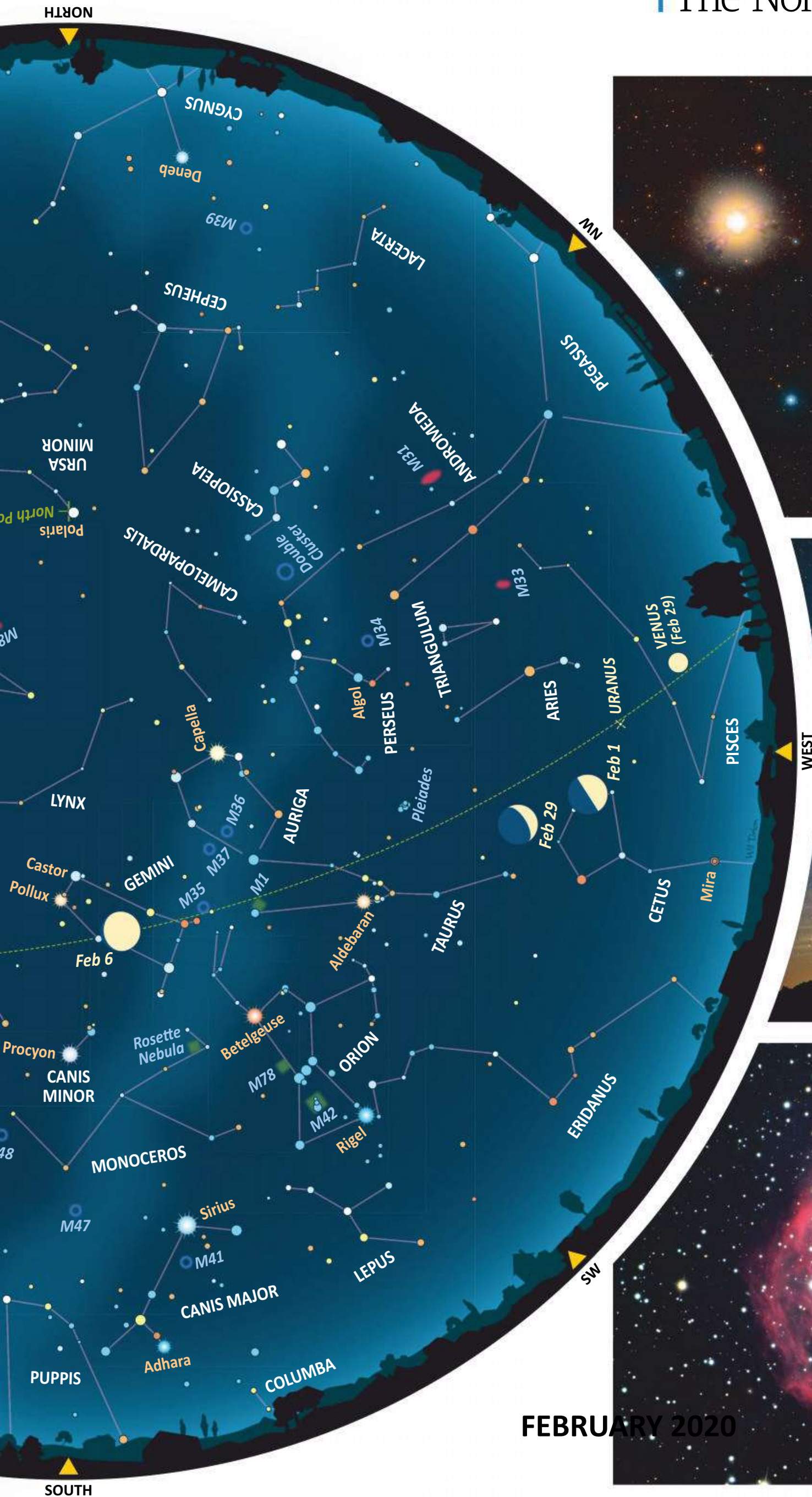
Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:

The night sky as it appears on 17 February 2020 at approximately 22:00 (GMT)



FEBRUARY 2020



Hyades star cluster

Source: Wiki © DSS / Giuseppe Donatiello



Constellation of Gemini

Source: Wiki © Benh LIEU SONG



Medusa Nebula (Abell 21)

Source: Wiki © Jschulman55



STARGAZER

Astroshots of the month

Send your astrophotography images to space@spaceanswers.com for a chance to see them featured in **All About Space**

The Tarantula Nebula
(30 Doradus)

Cory Schmitz



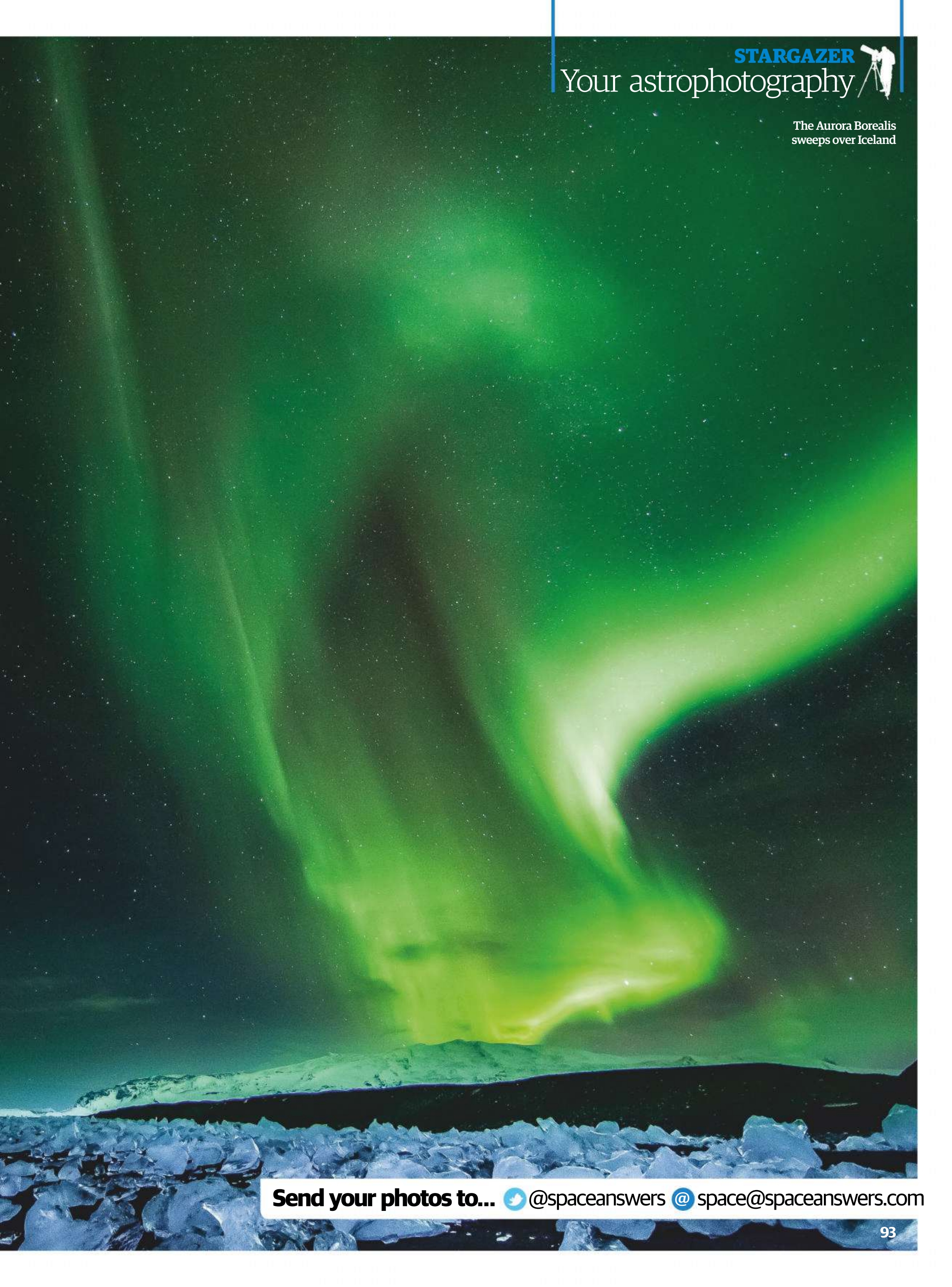
Johannesburg,
South Africa
"Ever since
space camp
and a model
rocketry
obsession as

a child, I've been enamoured by the universe. In 2011 I purchased my first telescope, a 10" Dobsonian, and one year later I took my first deep-space photo of the Great Globular Cluster in Hercules (M13) using a DIY equatorial platform. Since then I've imaged deep-sky objects, the lunar surface and planetary targets, wide-field landscapes and time-lapses."



Rho Ophiuchi

The Aurora Borealis
sweeps over Iceland



Send your photos to...  @spaceanswers  space@spaceanswers.com

Celestron Omni XLT 120

A quality telescope that is easily accessorised, this refractor is ideal for observing the Solar System and some bright deep-sky objects

Telescope advice

Cost: £449 (approx. \$568)

From: David Hinds Ltd

Type: Refractor

Aperture: 120mm (4.72")

Focal length: 990mm (39")

Best for...

-  Beginners and Intermediate
-  Medium budgets
-  Planetary viewing
-  Lunar viewing
-  Deep-sky objects
-  Basic astrophotography

For the price, the XLT 120 is of exceptional quality, especially if you are a keen observer of Solar System targets such as the planets and our Moon. Since you don't need tools to set up the telescope, it takes a mere five to ten minutes to put it together.

The XLT 120 is a fine example of a small to medium-sized refractor, and this became evident when we turned it to a selection of objects in a relatively clear March night sky. We took advantage of a full Moon with the Celestron Omni, and popping the supplied 25mm eyepiece, which provides a magnification of 40x, into the 1.25" star diagonal, we were soon studying the lunar surface. The telescope's lenses are of superb quality, manufactured with StarBright XLT coatings to ensure bright and crystal-clear views as we toured craters and mare, as well as lunar rilles and mountains. Bright crater Aristarchus was a stunning sight, as were the craters Kepler, Copernicus and Tycho, whose rays, made when material was thrown up during their progenitor impacts, could easily be detected by the refractor.

As we slewed across the Moon's surface, we noted the ease with

which the German Equatorial mount allowed the telescope tube to move. The mount's well-made stainless-steel tubular tripod legs are exquisite, providing excellent support to the telescope and a good, solid base when combined with the counterbalance for anyone wishing to try their hand at basic astrophotography.

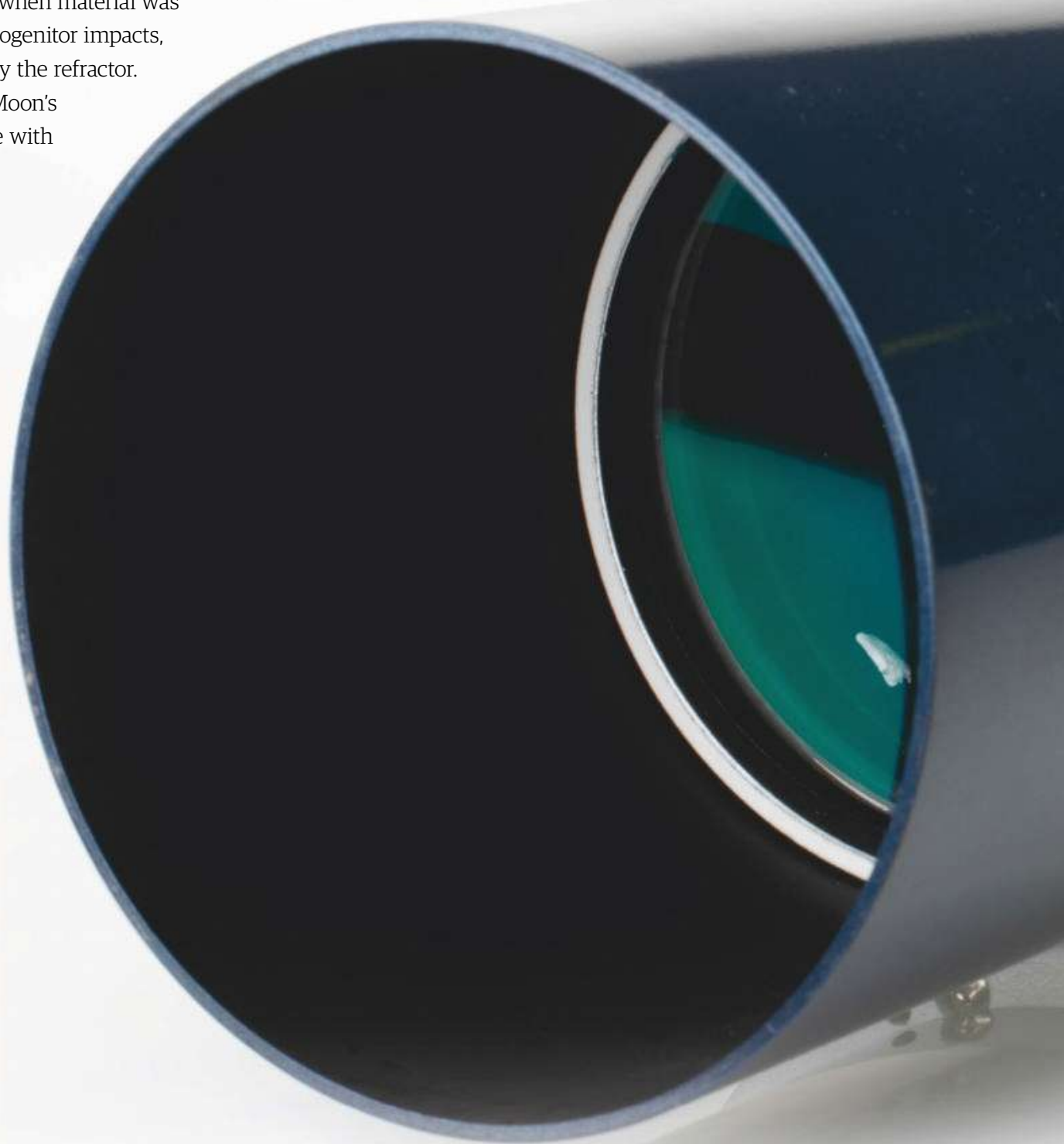
Sadly, we did notice a small degree of colour fringing, or chromatic aberration, which gave bright objects a purple to blue colouring. For the cost of the telescope, we did expect this common flaw with refractor telescopes to be prevalent in the XLT 120, but we were delighted to see that our views of the night sky were hardly affected. In fact, the chromatic aberration was so minor that we quickly forgot about this slight problem in the telescope's optical system.



Right (main): The tube is of impressive build and the refractor's optical system provides clear and sharp views of a variety of night-sky objects with only a degree of colour fringing

Left: A heavy-duty German Equatorial mount enables the telescope to be slewed smoothly, and combined with a sturdy tripod allows for a solid platform

Right (bottom): One multi-coated 25mm eyepiece is included with the telescope to provide a magnification of 40x



The XLT 120 unfortunately doesn't come with a great deal of accessories apart from the aforementioned diagonal and 25mm eyepiece. However, being versatile and having a useful maximum magnification of over 280x, the refractor will serve as a good instrument for years to come, ensuring that the observer, particularly a beginner, doesn't outgrow it. The multi-coated 25mm eyepiece has very good eye relief and we were delighted to see that it, as with all Celestron eyepieces, is of excellent quality and build.

Putting the 6x30 finderscope to the test, we noted the clear and sharp views when we used it to guide us to the very bright star Sirius, which shines at magnitude -1.46. We noted that views were sharp across a good proportion of the field of view with only slight trailing off at the edges of the field. We were quick to move over to gas giant Jupiter and its four largest moons - Ganymede, Io, Callisto and Europa - and were impressed with the view as the gas giant's disc popped into view and the satellites appeared as points of light. We did note a halo around the planet, which unfortunately didn't disappear until we popped in a filter.

"We noted that views were sharp across a good proportion of the field of view"

With Venus in the sky, we took the opportunity to observe it. As with views of many bright objects, there was purple colour fringing around the planet's bland disc. Red giant star Betelgeuse kept its stunning orange-red colour at 40x, while not too far away the Orion Nebula's diffuse gas and the Trapezium star cluster were picked up easily with the additional help of averted vision.

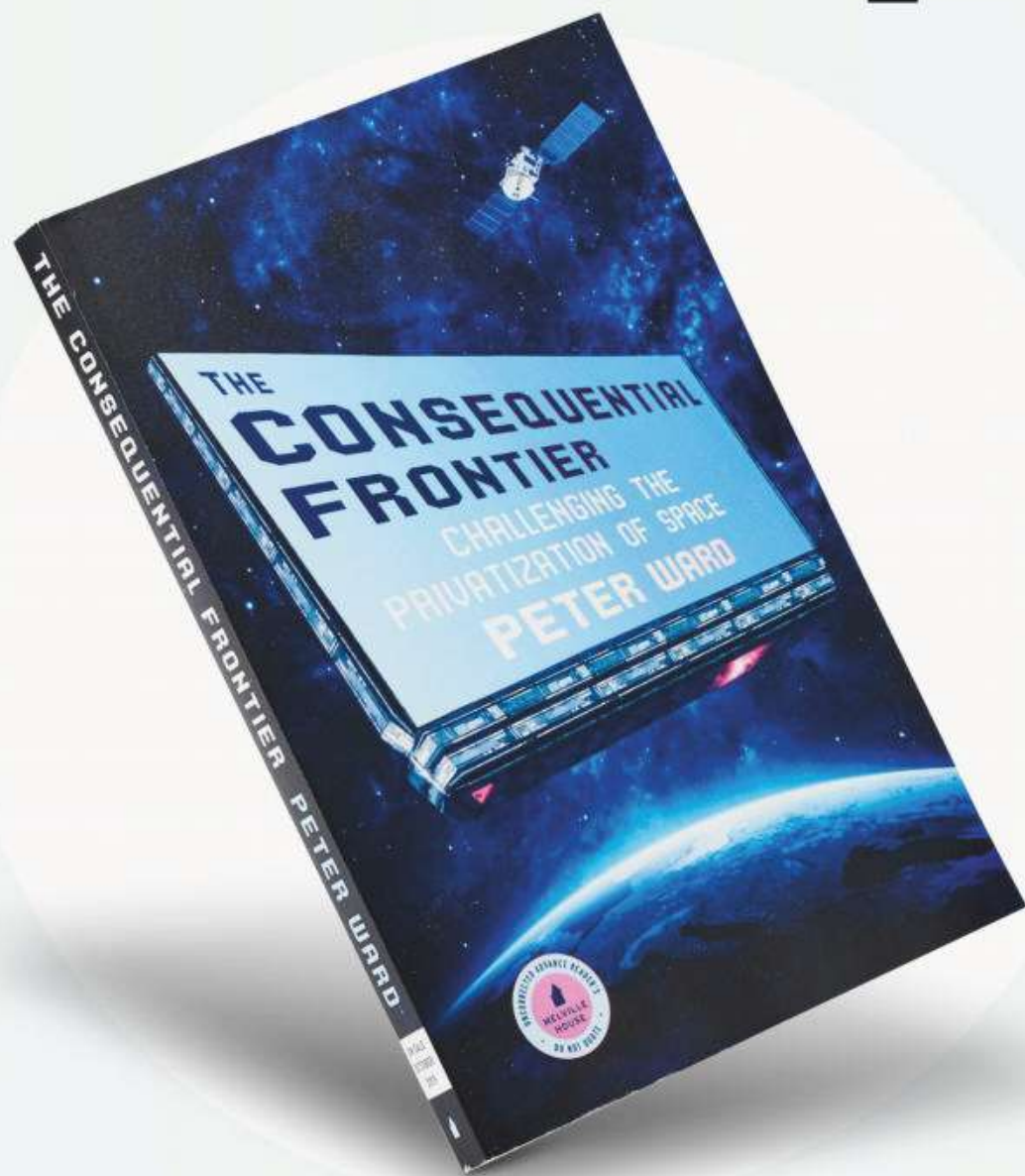
We can highly recommend the XLT 120. You don't get a great deal in the way of accessories, but you do get a decent optical system housed by a very well-built telescope tube combined with a sturdy mount. It might take some getting used to by novices, but it promises to last for many observing sessions.





In the shops

The latest books, apps, software, tech and accessories for space and astronomy fans alike



Book **The Consequential Frontier**

Cost: £25.00 / \$26.99 (Hardback)

From: Melville House

This in-depth work of reportage dares to ask what's at stake in privatising outer space. Earth is in trouble - so dramatically that we're now scrambling to explore space for valuable resources and a home for permanent colonisation. With the era of NASA's dominance now behind us, the private sector is winning this new space race. But if humans and their private wealth have made such a mess of Earth, who can say we won't do the same in space?

In *The Consequential Frontier*, business and technology journalist Peter Ward is raising this vital question before it's too late. Interviewing tech CEOs, inventors, scientists, lobbyists, politicians and future civilian astronauts, Ward sheds light on a whole industry beyond headline-grabbing rocket billionaires like Jeff Bezos and Elon Musk, and introduces the new generation of activists trying to keep it from rushing recklessly into the cosmos.

With optimism for what humans might accomplish in space if we could leave our tendency towards deregulation, inequality and environmental destruction behind, Ward shows just how much cooperation it will take to protect our universal resource and how beneficial it could be for all of us.

Software **Redshift 8 Premium**

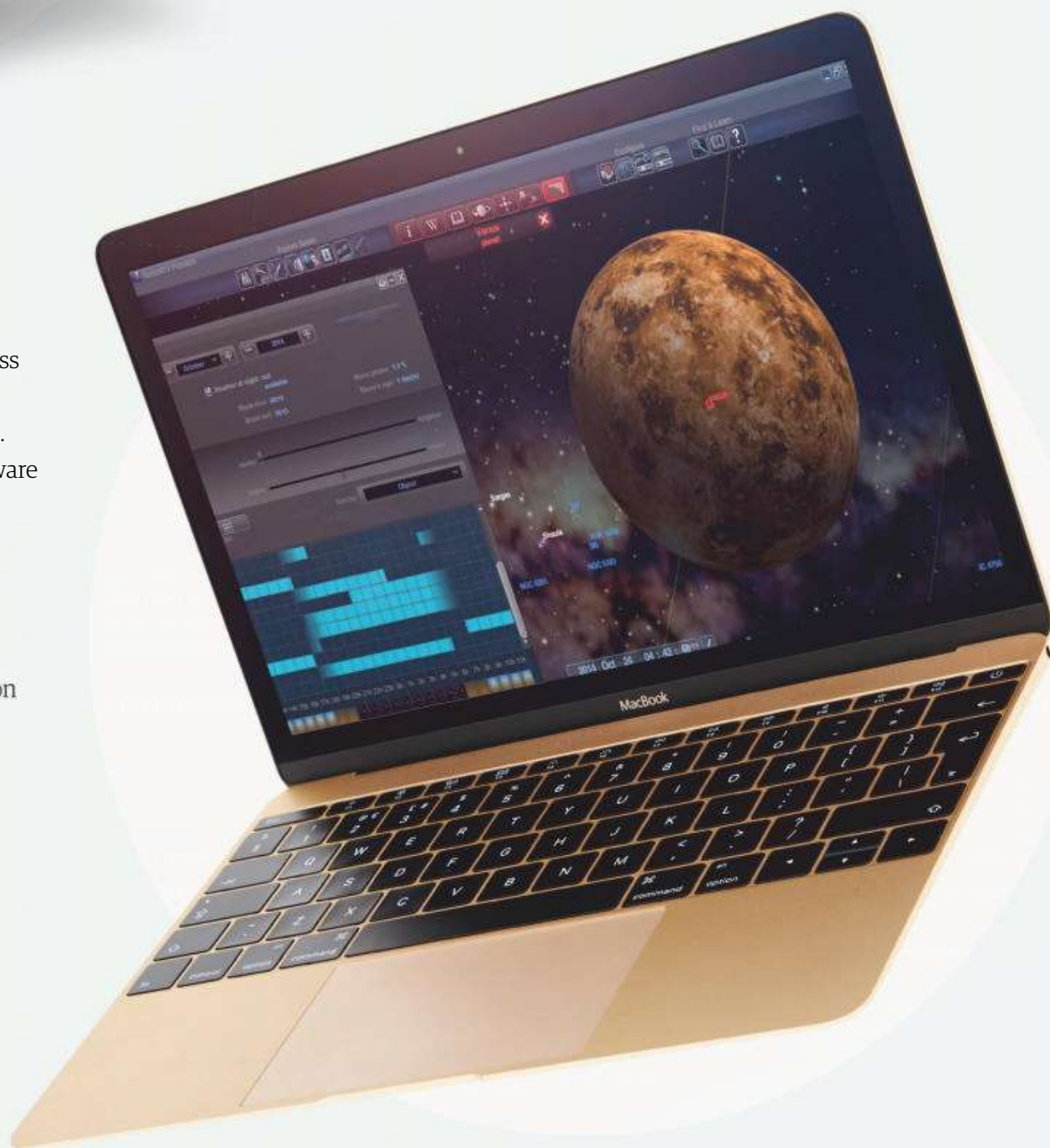
Cost: From £43.99 / \$44.99

From: redshift-live.com

Redshift is an extremely comprehensive guide to the heavens. Redshift 8, similar to the versions before it, allows you to travel across the Milky Way and beyond to give you a close-up view of planets, moons, asteroids and other celestial bodies within our Solar System. The Premium version is one of the most professional pieces of software available on the market. Within a few moments of using Redshift 8, we immediately realised that it was worth paying for over free, less superior planetarium software. However, in our opinion it would be improved if Redshift 8 was compatible with Mac OS X.

Redshift 8's design is impressive, but given that its interface has changed since versions 6 and 7, it took some time to find information on celestial events. Once we worked this out the software was easy to use. A glossary of astronomy terms is especially useful if you're looking to expand your stargazing vocabulary. We also discovered that we had to 'force quit' the software on several occasions - something that may infuriate users.

On top of a simulation of around 100 million stars, 1 million deep-sky objects and 500,000 asteroids, as well as 40 interactive multimedia tours, telescope control, breathtaking images, videos, animations and more, Redshift 8 offers several attractive extras including maps of solar eclipses.





App NASA Visualization Explorer

Cost: Free **From:** iOS and Android

With a treasure trove of information, this latest application from NASA is very educational and interactive, providing you with tidbits of information that are digestible so you don't have to take in too much all at once. Even better, it's entirely free for all iPad and iPhone users, providing you with the perfect companion to learn all about NASA, its missions, cutting-edge research and spacecraft, as well as general space science facts to keep you updated. New stories are posted up every week, so it's important that you're hooked up to WiFi or a suitable data connection on your iPhone.

We got stuck into the new updated version (1.9.11) of the NASA Visualization Explorer as soon as we downloaded it and found that there was no crashing of the movie player - a bug that put off many users of the earlier versions - and that this handy app played audio seamlessly.

With there always being something new to learn, plus stunning illustrations and images along the way, the NASA Visualization Explorer app gets a huge thumbs up!

"It's full of information that is digestible so you don't have to take in too much all at once"

Binoculars Helios Solana 10x50 binoculars

Cost: £42.99 **From:** Optical Vision Ltd

Helios Solana 10x50 Porro Prism Binoculars are a lightweight, comfortable, convenient and stylish binocular, ideal for birdwatching, astronomy, nature and general use. With their 10x magnification, they allow you to watch the scene closely and clearly, and the large size 50mm objective lenses increase light transmission and offer viewing even in low-light conditions.

The optical components have anti-reflective properties which assure the maximum light transmission and deliver bright, crisp images in the widest range of viewing conditions. The BK-7 Porro Prism design provides a wider field of view. The specially coated rubber-armoured body makes these binoculars extremely comfortable to hold, with a soft and luxurious feel, and protect them from any damage. The extra-large centre focus wheel gives an observer very smooth and accurate focusing.

The 10mm eye-relief design offers the viewer an entire 114-metre (374-foot) field of view very clearly. The soft fold-down rubber eyecups make these binoculars ideal for both spectacle users and non-glassers wearers and block peripheral light. They come with a soft, padded carrying case, neck strap and eyepiece cap to keep the binoculars safe during long travelling without any worry.



Oleg Ivanovich Skripochka

The Russian cosmonaut is a regular on board the ISS, due to finish his third visit this year

If you happen to be looking up at the night sky this month and catch a glimpse of the International Space Station (ISS) hurtling through the stars, take a second to comprehend that there are six astronauts on there doing incomparable work. One of these heroes is Russian cosmonaut Oleg Skripochka, a veteran of two ISS expeditions currently in the process of finishing a third - a feat which has only been completed by a handful of people in the entire world.

Skripochka was born on 24 December 1969 in Nevinnomyssk, Russia, formerly a part of the Soviet Union before its dissolution. He graduated from Bauman Moscow State Technical University in 1993 with a diploma in mechanical engineering, specialising in rocket construction. While studying to gain his diploma he was also working at the spacecraft manufacturer Energia as a test-metal worker, technician and eventually an engineer.

1997 was the year that Skripochka went to the Yuri Gagarin Cosmonaut Training Center, qualifying as a cosmonaut two years later and first serving as part of the backup crew to ISS Expedition 17. Eventually his time to shine arrived on 7 October 2010. On this day he was launched

to the ISS with fellow cosmonaut Aleksandr Kaleri and NASA astronaut Scott Kelly to undertake Expedition 25/26. Their five-month expedition included a plethora of research experiments for a range of subjects including physics and biometrics, even dabbling in a bit of public outreach.

A rather frightening scenario was recently revealed in Scott Kelly's book *Endurance: A Year in Space, a Lifetime of Discovery*, in which Kelly recalls an extravehicular activity (EVA) conducted by Skripochka which could have ended in disaster. During this spacewalk, Skripochka became untethered and began drifting away from the space station. If it wasn't for an antenna that bounced him back to

safety, Skripochka could have been lost to space!

Luckily, he made it back safely, and even Kelly didn't learn about the incident until five years later. That certainly didn't scare off Skripochka, who made a return to space in March 2016 as part of Expedition 47/48. This stay lasted for six months, crossing paths with European Space Agency astronaut Tim Peake on Expedition 46.

Now, as Skripochka orbits above us at an altitude of 400 kilometres (250 miles), he continues to maintain the historic and unique microgravity laboratory along with cosmonaut Aleksandr Skvortsov, NASA astronauts Christina Koch, Drew Morgan and Jessica Meir and ESA astronaut Luca Parmitano. This is where he will remain until spring 2020, but at the time of writing he has completed three EVAs totalling almost 17 hours. Skripochka has also been awarded the titles of Hero of the Russian Federation and Pilot-Cosmonaut of the Russian Federation, which again are only held by a select few.

Skripochka graduated from the 1997 cosmonaut group



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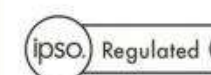
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"If it wasn't for an antenna that bounced him back to safety, Skripochka could have been lost to space"

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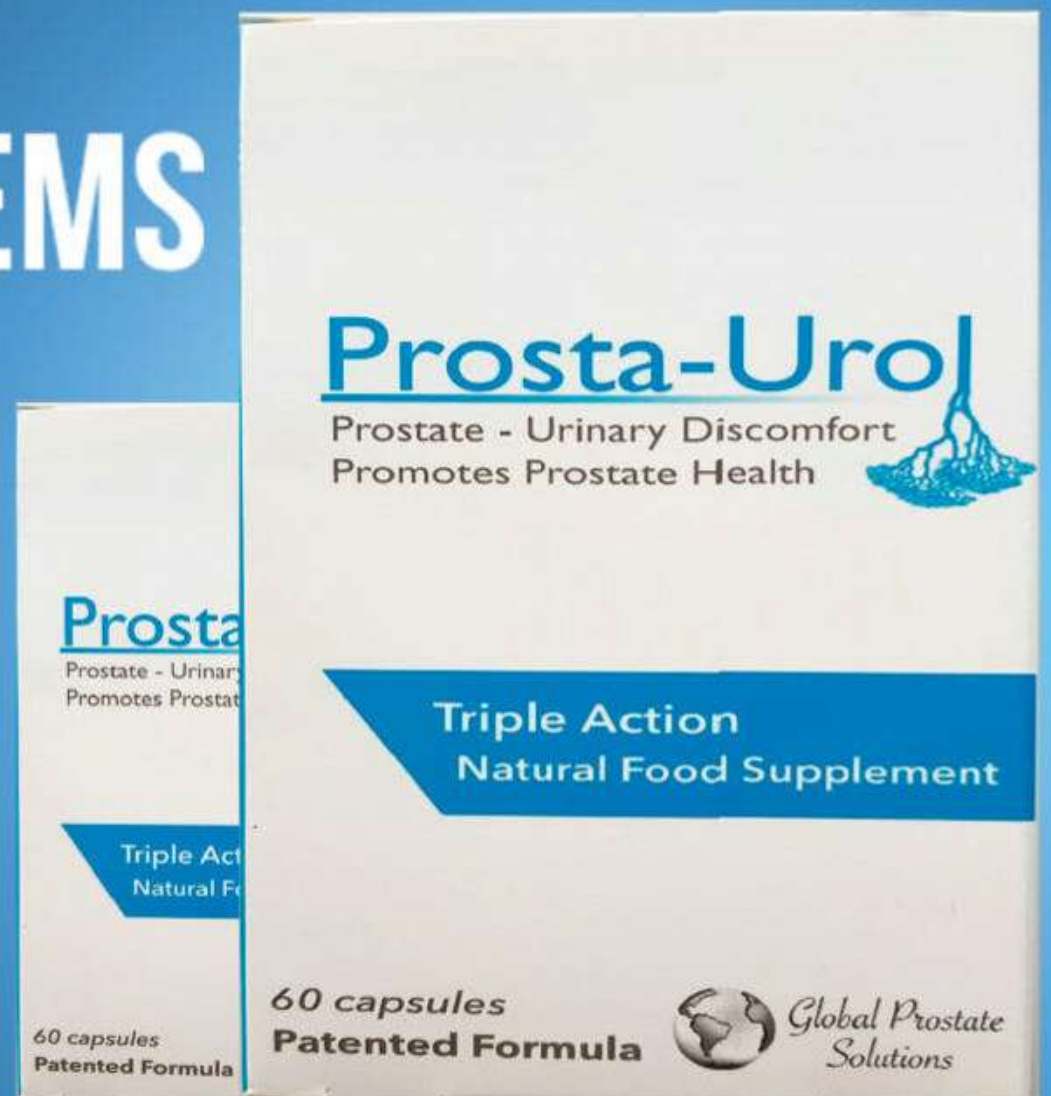
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